TECHNICAL MANUAL

OPERATOR'S ORGANIZATIONAL, DIRECT SUPPORT, GENERAL SUPPORT, AND DEPOT MAINTENANCE MANUAL (INCLUDING REPAIR PARTS INFORMATION AND SUPPLEMENTAL OPERATING, MAINTENANCE AND REPAIR PARTS INSTRUCTIONS)

FOR

ROLLER MOTORIZED, STEEL WHEEL 2 DRUM TANDEM, 10-14 TON (CCE) HYSTER MODEL C350B-D NSN 3895-00-578-0372

HEADQUARTERS, DEPARTMENT OF THE ARMY
FEBRUARY 1981

SAFETY IS YOUR BUSINESS

Safety, based on technical skill and years of experience, has been carefully built into your Detroit Diesel engine. Time, money and effort have been invested in making your diesel engine a safe product. The dividend you realize from this investment is your personal safety.

It should be remembered, however, that power-driven equipment is only as safe as the man who is at the controls. You are urged, as the operator of this diesel engine, to keep your fingers and clothing away from the revolving "V" belts, gears, blower, fan, drive shafts, etc.

An accident can be prevented with your help.

IMPORTANT SAFETY NOTICE

Proper service and repair is important to the safe, reliable operation of all motor vehicles. The service procedures recommended by Detroit Diesel Allison and described in this service manual are effective methods for performing service operations. Some of these service operations require the use of tools specially designed for the purpose. The special tools should be used when and as recommended.

It is important to note that some warnings against the use of specific service methods that can damage the vehicle or render it unsafe are stated in this service manual. It is also important to understand these warnings are not exhaustive. Detroit Diesel Allison could not possibly know, evaluate and advise the service trade of all conceivable ways in which service might be done or of the possible hazardous consequences of each way. Consequently, Detroit Diesel Allison has not undertaken any such broad evaluation. Accordingly, anyone who uses a service procedure or tool which is not recommended by Detroit Diesel Allison must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects.

TECHNICAL MANUAL
NO. 5-3895-348-14 & P

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC, *20 February 1981*

OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT,

GENERAL SUPPORT, AND DEPOT MAINTENANCE MANUAL

(INCLUDING REPAIR PARTS INFORMATION AND SUPPLEMENTAL

OPERATING, MAINTENANCE AND REPAIR PARTS INSTRUCTIONS)

ROLLER MOTORIZED, STEEL WHEEL 2 DRUM

TANDEM 10-14 TON (CCE)

HYSTER MODEL C350B-D

NSN 3895-00-578-0372

CONTRACT NO. DSA700-74-C-9024

REPORTING OF ERRORS

You can help improve this manual. If you find any mistake or if you know of a way to improve the procedures, please let us know. Mail your letter, or DA Form 2028 (Recommended Changes to Publications and Blank Forms) direct to: Commander, US Army Tank-Automotive Materiel Readiness Command, ATTN: DRSTA-MBS, Warren, MI 48090. A reply will be furnished to you.

This technical manual is an authentication of the manufacturers' commercial literature and does not conform with the format and content specified in AR 310-3, Military Publications. This technical manual does, however, contain available information that is essential to the operation and maintenance of the equipment.

PART I

Operators Manual

Series 53 Engines

Printed in U.S.A.

TO THE OPERATOR

This manual contains instructions on the operation and preventive maintenance of your Detroit Diesel engine. Sufficient descriptive material, together with numerous illustrations, is included to enable the operator to understand the basic construction of the engine and the principles by which it functions. This manual does not cover engine repair or overhaul.

Whenever possible, it will pay to rely on an authorized *Detroit Diesel Allison Service Outlet* for all your service needs from maintenance to major parts replacement. There are over 1500 authorized service outlets in the U.S. and Canada. They stock factory original parts and have the specialized equipment and personnel with technical knowledge to provide skilled and efficient workmanship.

The operator should familiarize himself thoroughly with the contents of the manual before running an engine, making adjustments, or carrying out maintenance procedures.

The information, specifications and illustrations in this publication are based on the information in effect at the time of approval for printing. Generally, this publication is reprinted annually. It is recommended that users contact an authorized *Detroit Diesel Allison Service Outlet* for information on the latest revision. The right is reserved to make changes at any time without obligation.

WARRANTY

The applicable engine warranty is contained in the form entitled POLICY ON OWNER SERVICE, available from authorized Detroit Diesel Allison Service Outlets.

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SUBJECT PAGE

DESCRIPTION

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively, as shown in Fig. 1. In contrast, a four-cycle engine requires four piston strokes to complete an operating cycle; thus, during one half of its operation, the four-cycle engine functions merely as an air pump.

A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports as shown in Fig. 1 (scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression as shown in Fig. 1 (compression).

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector as shown in Fig. 1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about halfway down, allowing the burned gases to escape into the exhaust manifold as shown in Fig. 1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, in two strokes; hence, it is a "two-stroke cycle".

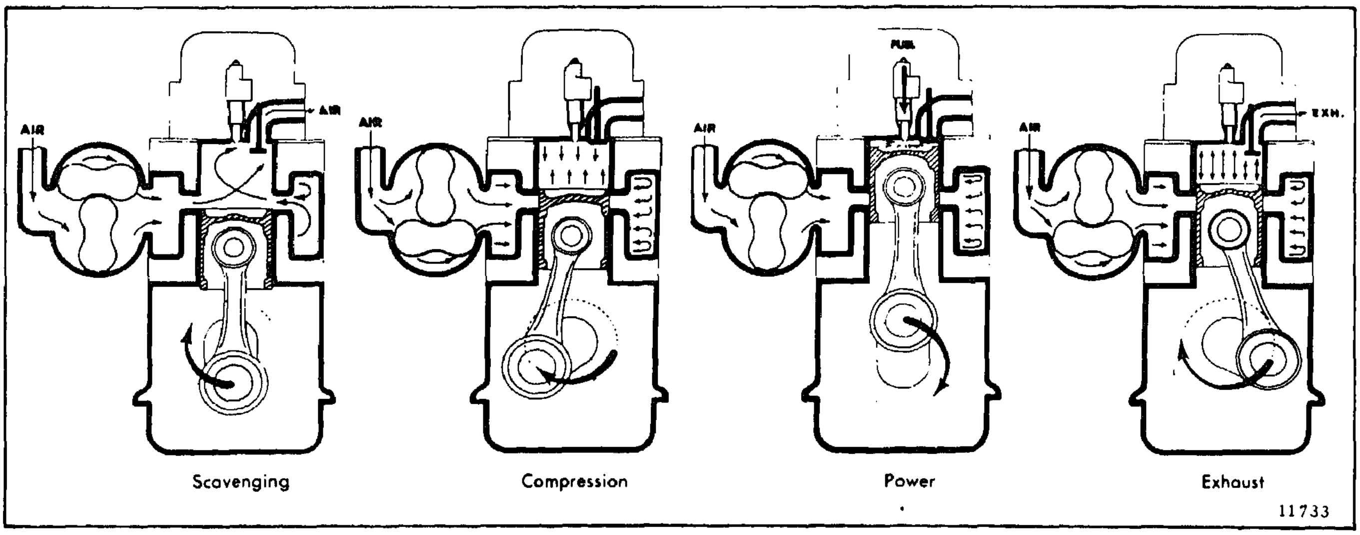


Fig. 1 - The Two-Stroke Cycle

GENERAL DESCRIPTION

The two-cycle diesel engines covered in this manual have the same bore and stroke and many of the major working parts such as injectors, pistons, connecting rods, cylinder liners and other parts are interchangeable

The In-line engines, including the inclined marine models, include standard accessories such as the blower, water pump, governor and fuel pump, which, on some models, may be located on either side of the engine regardless of the direction the crankshaft rotates. Further flexibility in meeting installation requirements is achieved with the cylinder head which can be installed to accommodate the exhaust manifold on either side of the engine.

The V-type engine uses many In-line engine parts, including the 3-53 cylinder head. The blower is mounted on top of the engine between the two banks of cylinders and is driven by the gear train. The governor is mounted on the rear end of the 6V-53 blower.

The meaning of each digit in the model numbering system is shown in Figs. 2 and 3. The letter L or R indicates left or right-hand engine rotation as viewed from the front of the engine. The letter A,B,C or D designates the blower and exhaust manifold location on the In-line engines as viewed from the rear of the engine while the letter A or C designates the location of the oil cooler and starter on the 6V-53 engine.

Each engine is equipped with an oil cooler, replaceable element type lubricating oil filter, fuel oil strainer, fuel oil filter, an air cleaner or air silencer, a governor, a heat exchanger and raw water pump or a fan and radiator, and a starting motor.

Full pressure lubrication is supplied to all main bearings, connecting rod bearings, and camshaft bearings, and to other moving parts.

Oil is drawn by suction from the oil pan through the intake screen and pipe to the oil pump where it is pressurized and delivered to the oil filter and the oil cooler. From the oil cooler, the oil enters oil galleries in the cylinder block and cylinder head for distribution to the main bearings, connecting rod bearings, camshaft bearings, rocker arm mechanism and other functional parts.

The cooling system has a centrifugal water pump which circulates the engine coolant through the oil cooler and water jackets. The engine temperature is regulated by a thermostat(s).

Fuel is drawn from the supply tank through the fuel strainer and enters a gear type fuel pump at the inlet side. Upon leaving the pump under pressure, the fuel is forced through the fuel filter into the inlet manifold where it passes through fuel pipes into the inlet side of the fuel injectors. The fuel is filtered through elements in the injectors and then atomized through small spray tip orifices into the combustion chamber. Excess fuel is returned to the fuel tank through the fuel outlet galleries and connecting lines.

Air for scavenging and combustion is supplied by a blower which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower first passes through an air cleaner or air silencer.

The engine may be started by either a hydraulic or an electric starting system.

The engine speed is regulated by a mechanical or hydraulic type engine governor, depending upon the engine application.

5043 — 5101

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENTS * (see below)	DESIGN VARIATION	SPECIFIC MODEL NUMBER AND STARTER—BLOWER ARRANGEMENT

APPLICATION DESIGNATION

5042-5100	MARINE
5043-5100	FAN TO F/W—INDUSTRIAL
5044-5100	POWER-BASE
5045-5100	GENERATOR
5047-5100	FAN TO F/W—VEHICLE

DESIGN VARIATION

5043-5000	"N" ENGINE
5043-5100	2 VALVE HEAD
5043-5200	4 VALVE HEAD
5042-2302	TURBOCHARGER

STARTER—BLOWER ARRANGEMENT

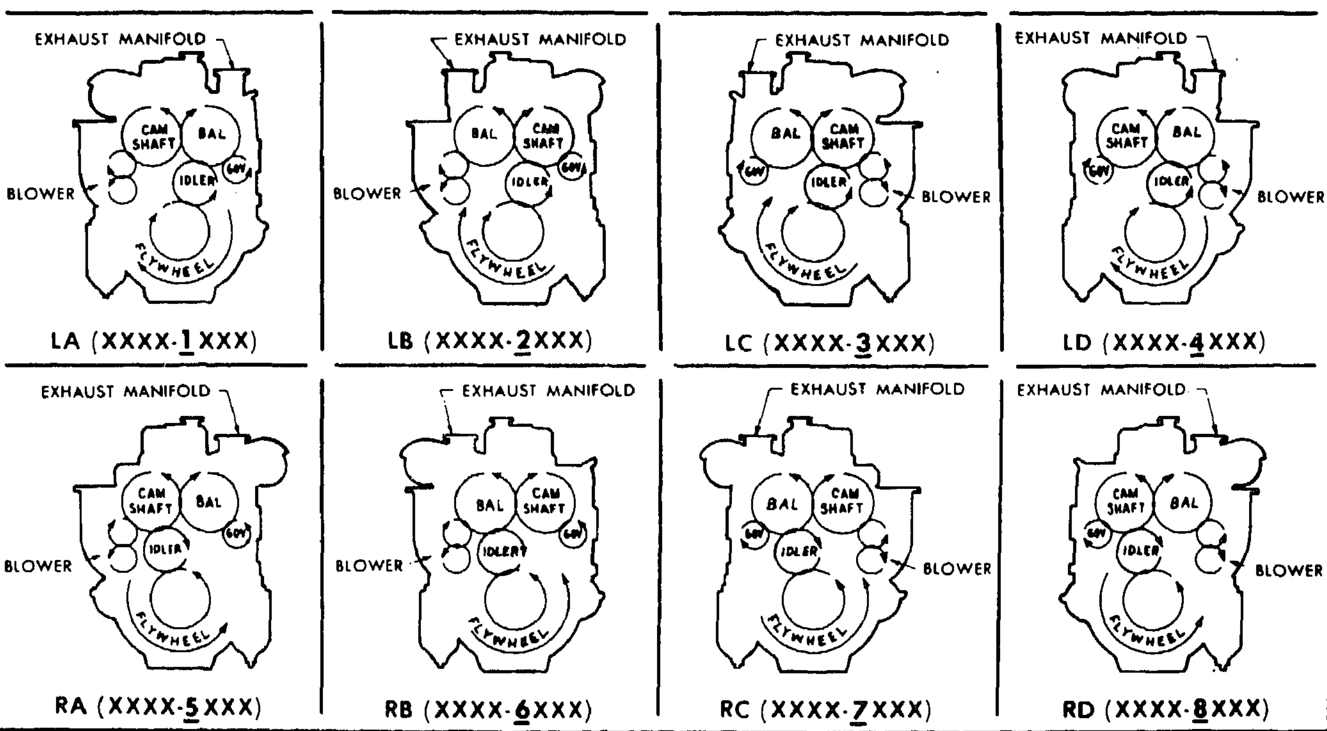
Odd number in last digit designates starter opposite blower.

Even number in last digit designates starter same side as blower.

*** 2, 3, 4-53 BASIC ENGINE ARRANGEMENTS**

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A-B-C-D designates location of exhaust manifold and blower as viewed from the flywheel end of the engine.



ALL ABOVE VIEWS FROM REAR (FLYWHEEL) END OF ENGINE 12223

Fig. 2 - In-Line Engine Model Description, Rotation and Accessory Arrangement

5 0 6 3 — 5 2 0 0

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENT * (see below)	DESIGN VARIATION	SPECIFIC MODEL NUMBER

APPLICATION DESIGNATION

5062-3000 MARINE
5063-5200 FAN to F/W-INDUSTRIAL
5064-5200 POWER-BASE
5065-5200 GENERATOR
5067-5040 FAN to F/W VEHICLE
5082-5000 MARINE
5083-5000 FAN to F/W INDUSTRIAL
5087-5040 FAN to F/W VEHICLE

DESIGN VARIATION

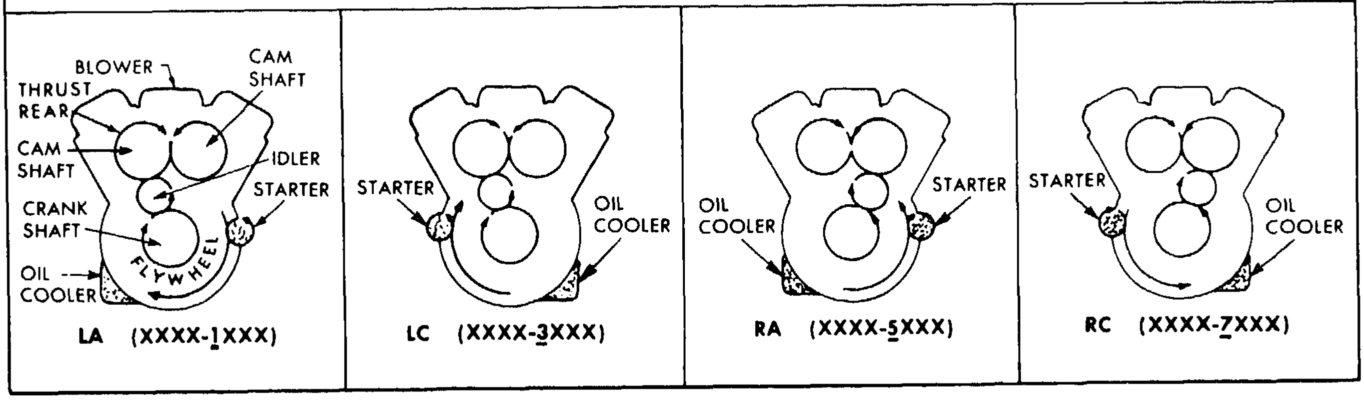
5062-3000 "N" ENGINE
5063-5200 4 VALVE HEAD

* BASIC ENGINE ARRANGEMENTS

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A and C designates location of starter and oil cooler as viewed from the flywheel end of the engine.

Cylinder Bank: Left and right cylinder banks are determined from the flywheel end of the engine.



ALL ABOVE VIEWS FROM REAR FLYWHEEL END OF ENGINE

Fig. 3 - 6V Engine Model Description, Rotation and Accessory Arrangement

GENERAL SPECIFICATIONS

	3-53	4-53	6V-53
Type	2 Cycle	2 Cycle	2 Cycle
Number of cylinders	3	4	6
Bore	3.875 in. (98 mm)	3.875 in. (98 mm)	3.875 in. (98 mm)
Stroke	4.5 in. (114 mm)	4.5 in. (114 mm)	4.5 in. (114 mm)
Compression Ratio (nominal)(standard engines)	17 to 1	17 to 1	17 to 1
Compression Ratio (nominal)("N" engines)	21 to 1	21 to 1	21 to 1
Total Displacement - cubic inches	159	212	318
Total Displacement - litres	2.61	3.48	5.22
Number of main bearings	4	5	4

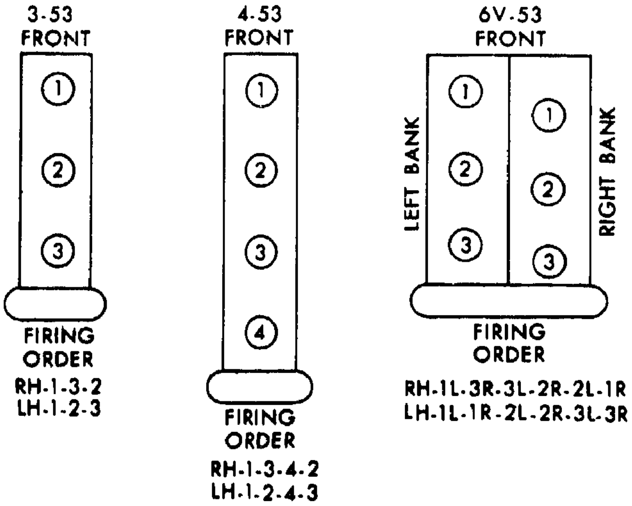


Fig. 4 - Series 53 Cylinder Arrangement

ENGINE MODEL AND SERIAL NUMBER DESIGNATION

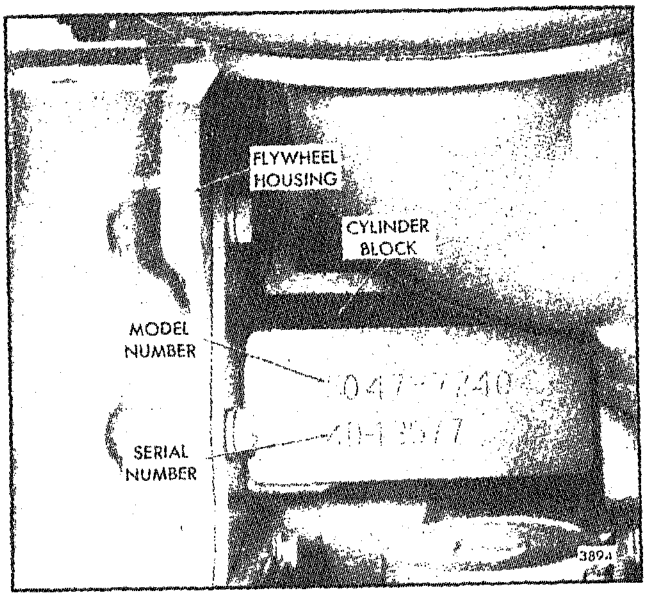


Fig. 5 - Typical Model and Serial Numbers as Stamped on Cylinder Block (In-Line Engine)

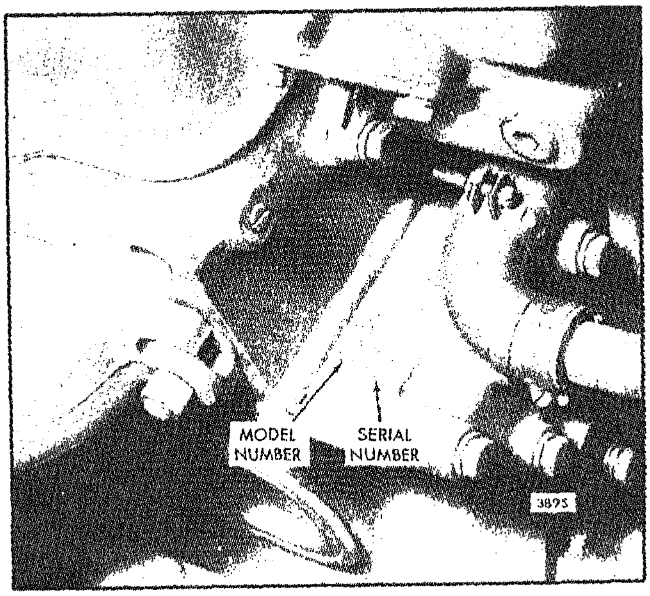


Fig. 6 - Typical Model and Serial Numbers as Stamped on Cylinder Block (6V Engine)

On the In-line engines, the model number and serial number are stamped on the right-hand side of the cylinder block in the upper rear corner (Fig. 5). The model number and serial number on the V-type engine is located on the top right-hand front corner of the cylinder block, as viewed from the rear of the engine (Fig. 6).

An option plate, attached to the valve rocker cover, is also stamped with the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 7).

With any order for parts, the engine model number and serial number must be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

Power take-off assemblies, torque converters, hydraulic marine gears, etc. may also carry name plates pertaining to the particular assembly to which they are attached. The information on these name plates is useful when ordering parts for these assemblies.

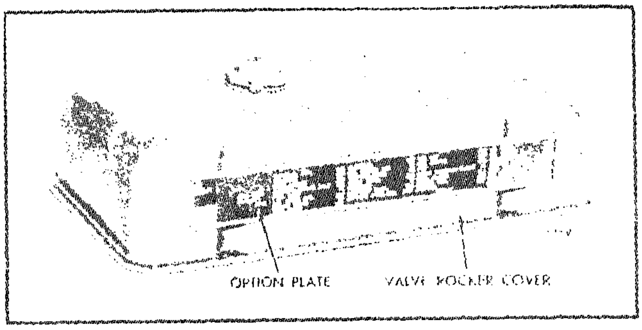
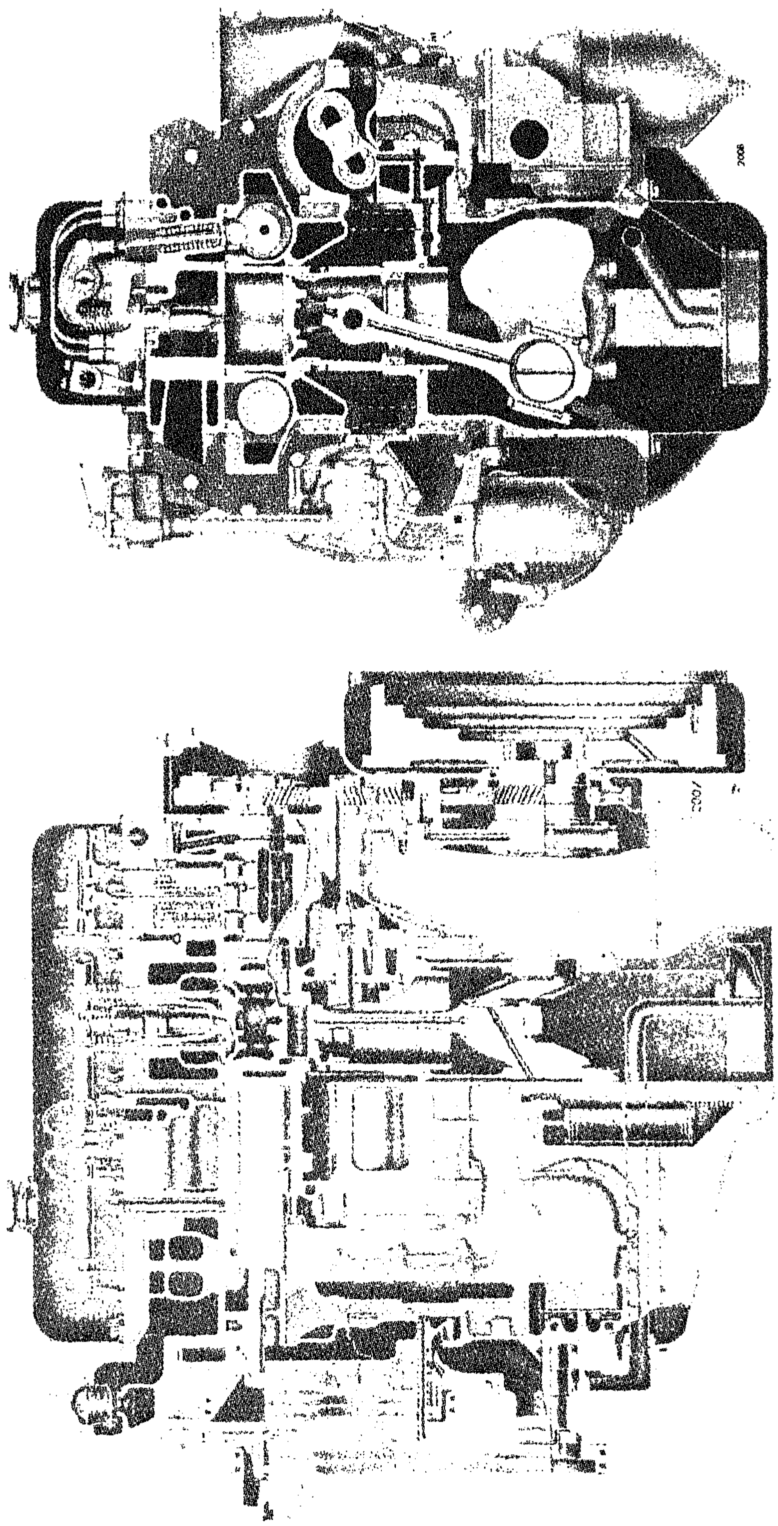


Fig. 7 - Option Plate

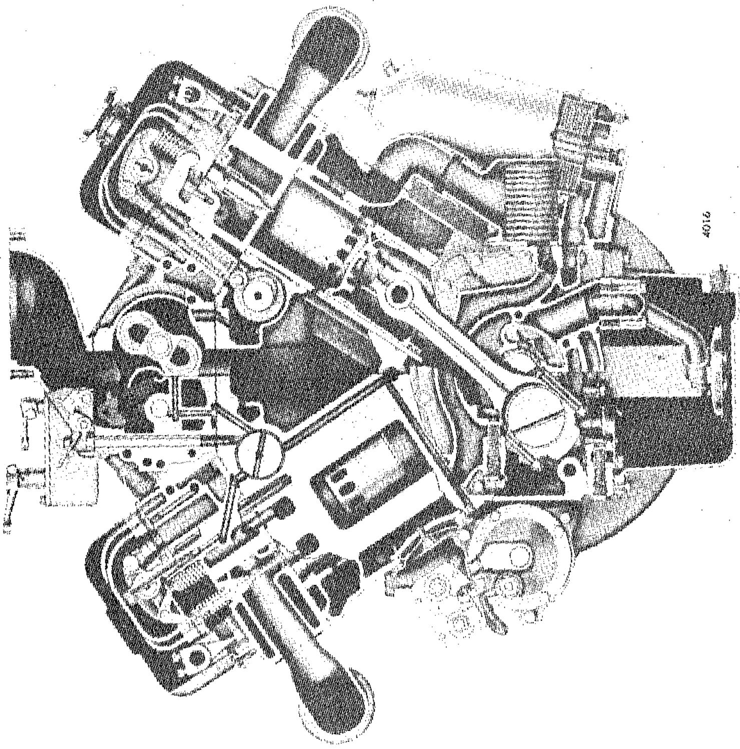
BUILT-IN PARTS BOOK

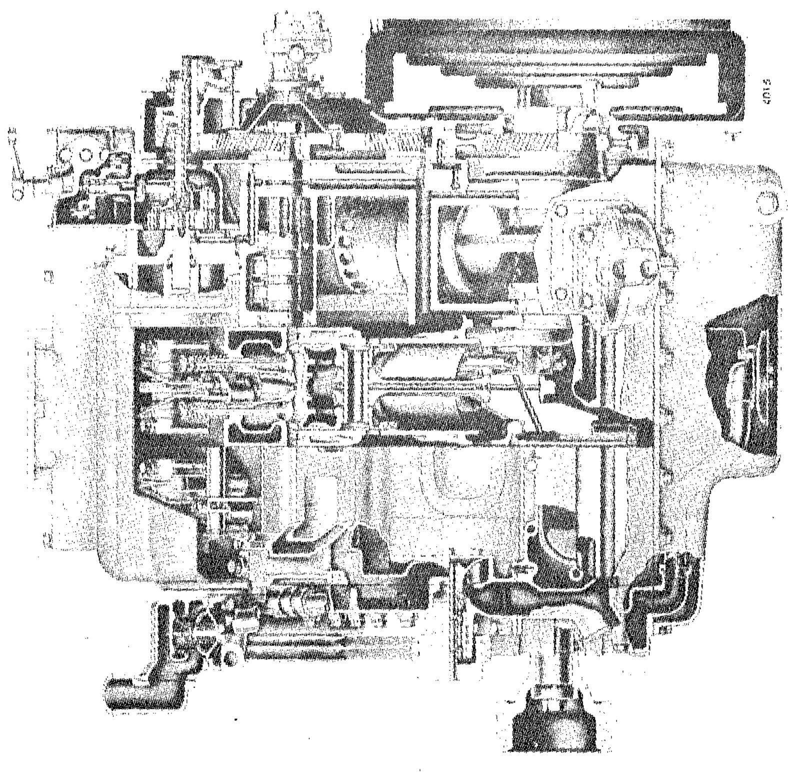
The *Built-In Parts Book* is an anodized aluminum plate (Option Plate) that fits into a retainer on the engine valve rocker cover and contains the necessary information required when ordering parts. It is recommended that the engine user read the section on the *Built-In Parts Book* in order to take full advantage of the information provided on the engine option plate.

Numerous exploded view type illustrations are included to assist the user in identifying and ordering service parts.



Cross Section Views of a Typical In-Line Engine





Cross Section Views of a Typical 6V-53 Engine

ENGINE SYSTEMS

The Series 53 Detroit Diesel engines incorporate four basic systems which direct the flow of fuel, air, lubricating oil, and engine coolant.

A brief description of each of these systems and their components, and the necessary maintenance and adjustment procedures are given in this manual.

FUEL SYSTEM

The fuel system (Figs. 1 and 2) consists of the fuel injectors, fuel pipes, fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and the necessary connecting fuel lines.

On In-line engines, a restricted fitting is located in the cylinder head fuel return manifold outlet to maintain pressure within the fuel system. On V-type engines, this restricted fitting is located in the left-bank cylinder head.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Upon leaving the pump under pressure, the fuel is forced through the fuel filter and into the fuel inlet manifold where it passes through fuel pipes into the inlet side of each fuel injector. The fuel is filtered through elements in the injectors and atomized through small spray tip orifices into the combustion chamber. Surplus fuel, returning from the injectors, passes through the fuel return manifold and connecting fuel lines back to the fuel tank.

The continuous flow of fuel through the injectors helps to cool the injectors and remove air from the fuel system.

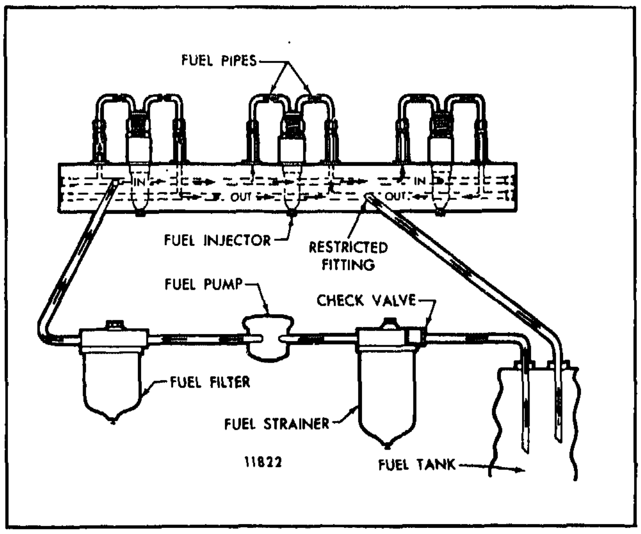


Fig. 1 - Schematic Diagram of Typical Fuel System - In-Line Engine

A check valve may be installed between the fuel strainer and the source of supply as optional equipment to prevent fuel drain back when the engine is not running.

Fuel Injector

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder. The injector creates the high pressure necessary for fuel injection, meters the proper amount of fuel, atomizes the fuel and times the injection into the combustion chamber.

Since the injector is one of the most important and carefully constructed parts of the engine, it is recommended that the engine operator replace the injector as an assembly if it is not operating properly. Authorized *Detroit Diesel Allison Service Outlets* are properly equipped to service injectors.

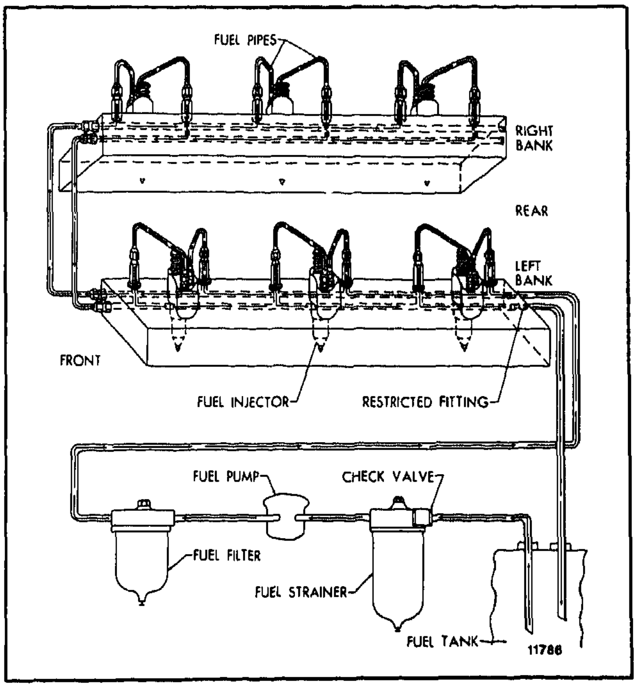


Fig. 2 - Schematic Diagram of Typical Fuel System - V-type Engine

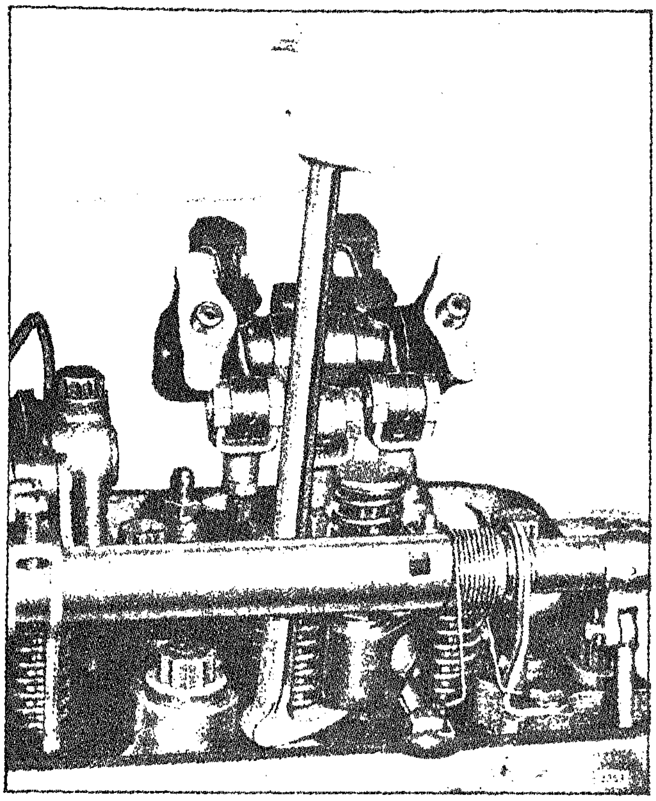


Fig. 3 - Removing Injector from Cylinder Head

Remove Injector

An injector may be removed in the following manner:

1. Clean and remove the valve rocker cover.

2. Disconnect the fuel pipes from both the injector and the fuel connectors.

3. Immediately after removing the fuel pipes, cover the injector inlet and outlet fittings with shipping caps to prevent dirt from entering.

4. Turn the crankshaft manually in the direction of engine rotation or crank the engine with the starting motor, if necessary, until the rocker arms for the particular cylinder are aligned in a horizontal plane.

> **CAUTION:** If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as the bolt will be loosened. Remove the starting motor and use a pry bar against the teeth of the flywheel ring gear to turn the crankshaft.

5. Remove the two rocker shaft bracket bolts and swing the rocker arm assembly away from the injector and valves.

6. Remove the injector clamp bolt, washer and clamp.

7. Loosen the inner and outer adjusting screws on the injector rack control lever and slide the lever away from the injector.

8. Free the injector from its seat as shown in Fig. 3 and lift it from the cylinder head.

9. Cover the injector hole in the cylinder head to keep foreign particles out of the cylinder.

Install Injector

Before installing an injector, be sure the beveled seat of the injector tube is free from dirt particles and carbon deposits.

A new or reconditioned injector may be installed by reversing the sequence of operations given above for removal.

Be sure the injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter until it runs out the outlet filter.

> **CAUTION:** On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridge before, during and after tightening the rocker shaft bracket bolts.

Do not tighten the injector clamp bolt to more than 20-25 lb-ft (27-34 Nm) torque, as this may cause the moving parts of the injector to bind. Tighten the rocker shaft bolts to 50-55 lb-ft (68-75 Nm) torque.

Align the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 and a torque wrench to tighten the fuel pipe nuts to 12-15 lb-ft (16-20 Nm) torque.

> **CAUTION:** Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

Time the injector, position the injector rack control lever and adjust the exhaust valve clearance (cold setting) as outlined in the engine tune-up procedure. If all of the injectors have been replaced, perform a complete tune-up on the engine.

Fuel Pump

A positive displacement gear-type fuel pump is attached to the governor or blower on the In-line engines and to the flywheel housing on the V-type engines.

A spring-loaded relief valve, incorporated in the pump body, normally remains in the closed position, operating only when the pressure on the outlet side (to the fuel filter) becomes excessive due to a plugged filter or fuel line.

The fuel pump incorporates two oil seals. Two tapped holes are provided in the underside of the pump body, between the oil seals, to permit a drain tube to be attached. If fuel leakage exceeds one drop per minute, the seals must be replaced. An authorized *Detroit Diesel Allison Service Outlet* is properly equipped to replace the seals.

Fuel pumps are furnished in either left or right-hand rotation, according to the engine model, and are stamped RH or LH. These pumps are not interchangeable and cannot be rebuilt to operate in an opposite rotation.

Fuel Strainer and Fuel Filter

A replaceable-element type fuel strainer and fuel filter (Fig. 4) are used in the fuel system to remove impurities from the fuel. The strainer removes the larger particles and the filter removes the small foreign particles.

The fuel strainer and fuel filter are basically identical in construction, both consisting of a cover, shell and replaceable element. Since the fuel strainer is placed between the fuel supply tank and the fuel pump, it functions under suction; the fuel filter, which is installed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure.

Replace the elements as follows:

1. With the engine shut down, place a suitable container under the fuel strainer or filter and open the drain cock. The fuel will drain more freely if the cover nut is loosened slightly.

2. Support the shell, unscrew the cover nut and remove the shell and element.

3. Remove and discard the element and gasket. Clean the shell with fuel oil and dry it with a cloth or compressed air.

4. Place a new element, which has been thoroughly

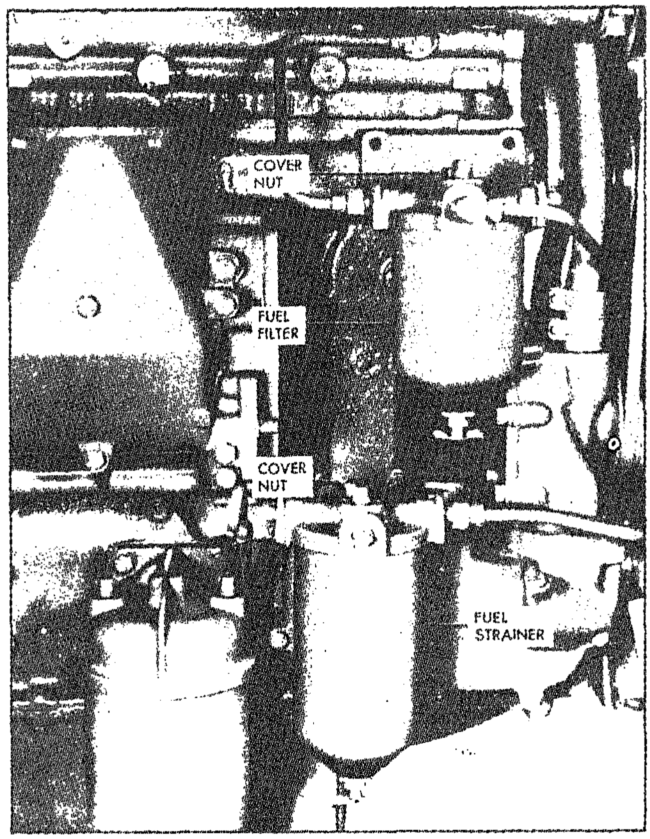


Fig. 4 - Typical Fuel Strainer and Filter Mounting

soaked in clean fuel oil, over the stud and push it down on the seat. Close the drain cock and fill the shell approximately two-thirds full with clean fuel oil.

5. Affix a new shell gasket, place the shell and element into position under the cover and start the cover nut on the shell stud.

6. Tighten the cover nut only enough to prevent fuel leakage.

7. Remove the plug in the strainer or filter cover and fill the shell with fuel. Fuel system primer J 5956 may be used to prime the fuel system.

8. Start and operate the engine and check the fuel system for leaks.

Spin-On Type Fuel Filter

A spin-on fuel strainer and fuel filter (Fig. 5) is used on certain engines. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly. No separate springs or seats are required to support the filters.

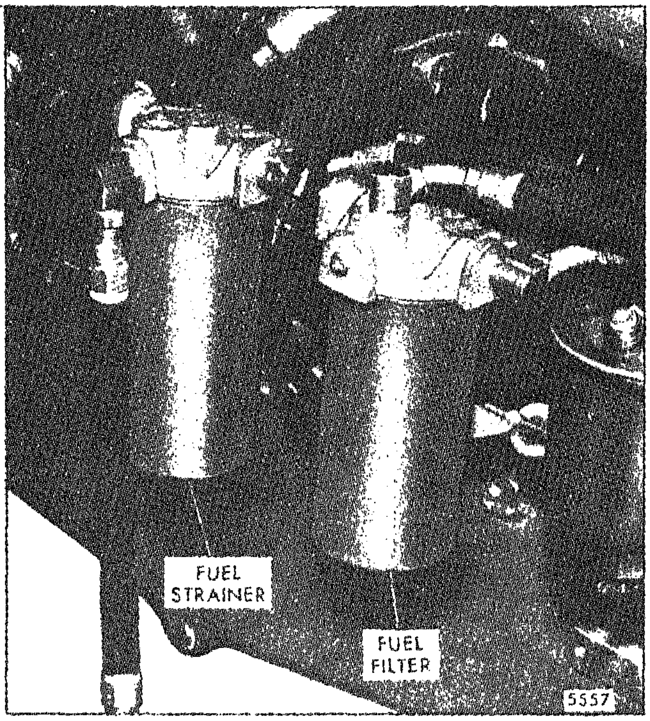


Fig. 5 - Typical Spin-On Type Fuel Strainer and Fuel Filter Mounting

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No drain cocks are provided on the spin-on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

A 1" diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.

2. Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new filter assembly and tighten it to two-thirds of a turn beyond gasket contact.

4. Start the engine and check for leaks.

Fuel Tank

Refill the fuel tank at the end of each day's operation to prevent condensation from contaminating the fuel.

> **CAUTION:** A galvanized steel tank should never be used for fuel storage because the fuel oil reacts chemically with the zinc coating to form powdery flakes which quickly clog the fuel strainer and filter and damage the fuel pump and the fuel injectors.

AIR SYSTEM

In the scavenging system used in two-cycle engines, illustrated in Figs. 6 and 7, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air silencer or air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower. The continuous discharge of fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners.

The angle of the ports in the cylinder liner creates a uniform swirling motion to the intake air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

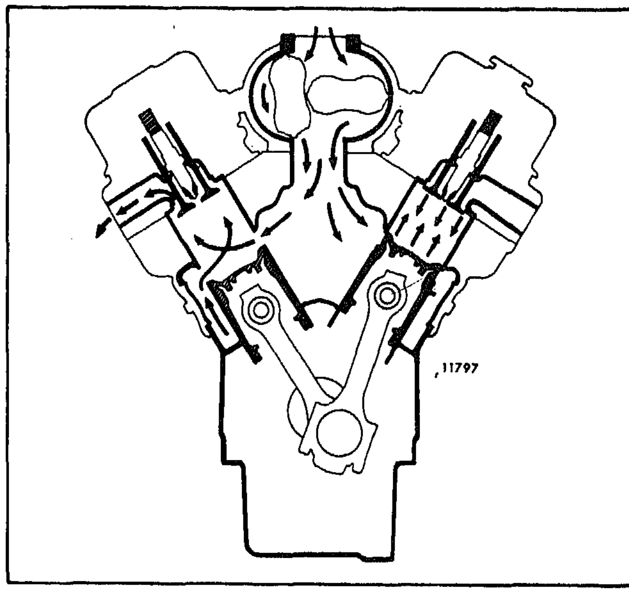


Fig. 7 - Air Intake System Through Blower and Engine (6V-53 Engine)

Air Cleaners

Several types of air cleaners are available for use with industrial engines. The light-duty oil bath air cleaner is used on most models. However, a heavy-duty oil bath type or a dry type air cleaner may be installed where the engine is operating in heavy dust concentrations.

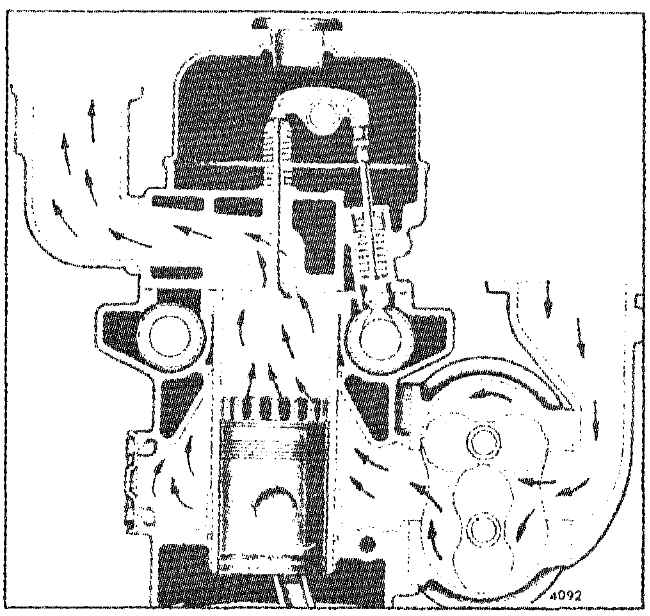


Fig. 6 - Air Intake System Through Blower and Engine (In-line Engine)

The air cleaners are designed for fast, easy disassembly to facilitate efficient servicing. Maximum protection of the engine against dust and other forms of air contamination is possible if the air cleaner is serviced at regular intervals.

The *light-duty oil bath type air cleaner* (Fig. 8) consists of a metal wool cleaning element supported inside of a housing which contains an oil reservoir. A chamber beneath the oil reservoir serves as a silencer for the incoming air to the blower. Air is drawn into the cleaner by the blower and passes over the top of the oil bath, where a major portion of the dirt is trapped, then up through the metal wool, where the finer particles are removed, and then down the central duct to the blower.

The *heavy-duty oil bath type air cleaner* (Fig. 9) consists of the body and fixed filter assembly which filters the air and condenses the oil from the air stream so that only dry air enters the engine. The condensed oil is returned to the cup where the dirt settles out of the oil and the oil is recirculated. A removable element assembly removes a major part of the dust from the air stream thereby decreasing the dust load to the fixed element. An inner cup, which can be removed from the outer (oil cup), acts as a baffle in directing the oil-laden air to the element and also controls the amount of oil in circulation and meters the oil to the element. The oil cup supports the inner cup and is a reservoir for oil and a settling chamber for dirt.

Service the *light-duty oil bath air cleaner* as follows:

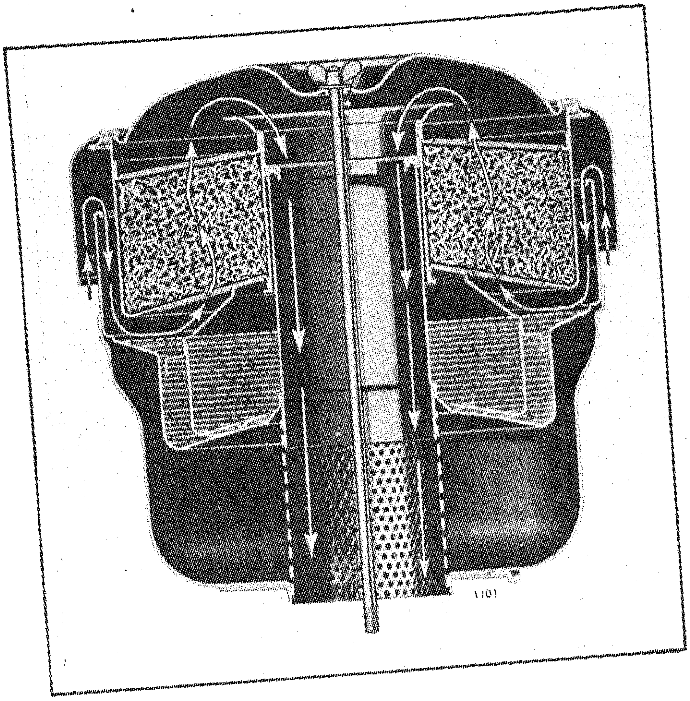


Fig. 8 - Light-Duty Oil Bath Air Cleaner

1. Loosen the wing bolt and remove the air cleaner assembly from the air inlet housing. The cleaner may then be separated into two sections; the upper section or body assembly contains the filter element, the lower section consists of the oil cup, removable inner cup or baffle and the center tube.

2. Soak the body assembly and element in fuel oil to loosen the dirt; then flush the element with clean fuel oil and allow it to drain thoroughly.

3. Pour out the oil, separate the inner cup or baffle from the oil cup, remove the sludge and wipe the baffle and outer cup clean.

4. Push a lint-free cloth through the center tube to remove dirt or oil.

5. Clean and check all of the gaskets and sealing surfaces to ensure air tight seals.

6. Refill the oil cup to the oil level mark only, install the baffle, and reassemble the air cleaner.

... housing before installing the air

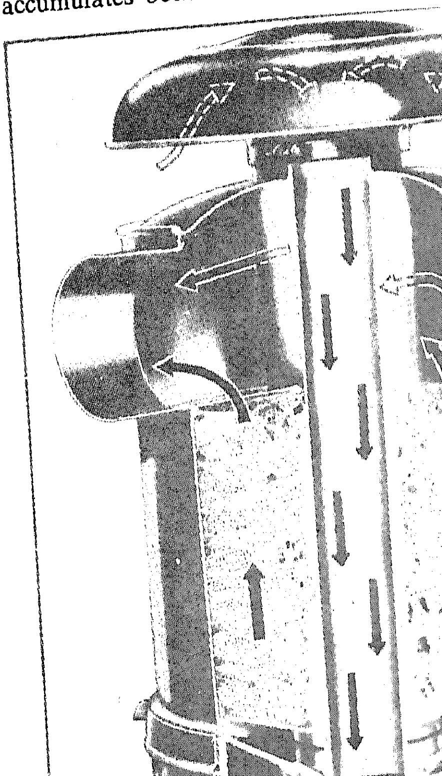
Tighten the wing bolt until the air cleane
mounted.

Service the *heavy-duty oil bath air cleaner* a

1. Loosen the wing nuts and detach the l
of the air cleaner assembly.

2. Remove the detachable screen by l
wing nuts and rotating the screen one-qua

One of the most important steps in prop
the tray type oil bath air cleaner is a ste
overlooked. Unless the filter tray i
cleaned, satisfactory performance of the
be realized. The presence of fibrous mat
the air is often underestimated and is t
of the malfunctioning of heavy-duty air
material comes from plants and trees
budding season and later from airborne
same sources. Figure 10 illustrates t
plugging in a tray that is 50% plugged.
areas in the mesh are accumulations
material. When a tray is plugged in
washing in a solvent or similar washin
not clean it satisfactorily. It must be
high pressure air or steam to remove t
accumulates between the layers of scr



clean tray is held up to the light, an even pattern of light should be visible. It may be necessary, only as a last resort, to burn off the lint. Extreme care must be taken to prevent melting the galvanized coating in the tray screens. Some trays have equally spaced holes in the retaining baffle. Check to make sure that they are clean and open. Figure 11 illustrates a thoroughly cleaned tray. The dark spots in the mesh indicate the close overlapping of the mesh and emphasize the need for using compressed air or steam. It is suggested that users of heavy-duty air cleaners have a spare tray on hand to replace the tray that requires cleaning. Having an extra tray available makes for better service and the dirty tray can be cleaned thoroughly as recommended. Spare trays are well worth their investment.

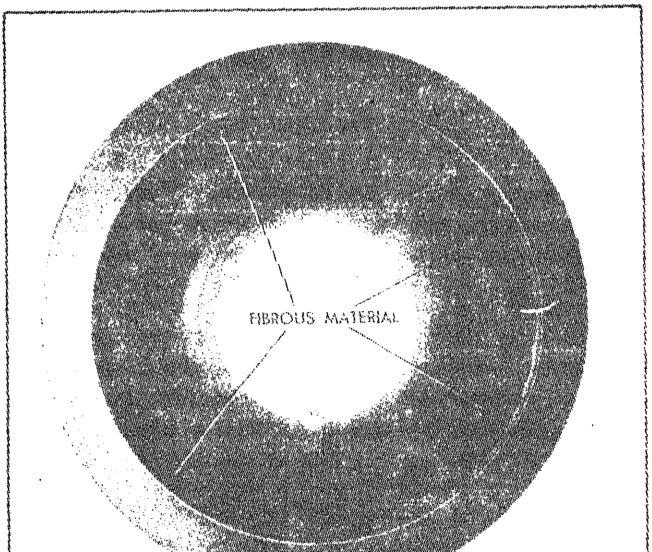
3. Pour out the oil, separate the inner cup or baffle from the oil or outer cup, remove the sludge and wipe the baffle and outer cup clean.

4. Clean and inspect the gaskets and sealing surfaces to ensure an air tight seal.

5. Reinstall the baffle in the oil cup and refill to the proper oil level with the same grade of oil being used in the engine.

6. Remove the hood and clean by brushing, or by blowing out with compressed air. Push a lint-free cloth through the center tube to remove dirt or oil from the walls.

7. Inspect the lower portion of the air cleaner body



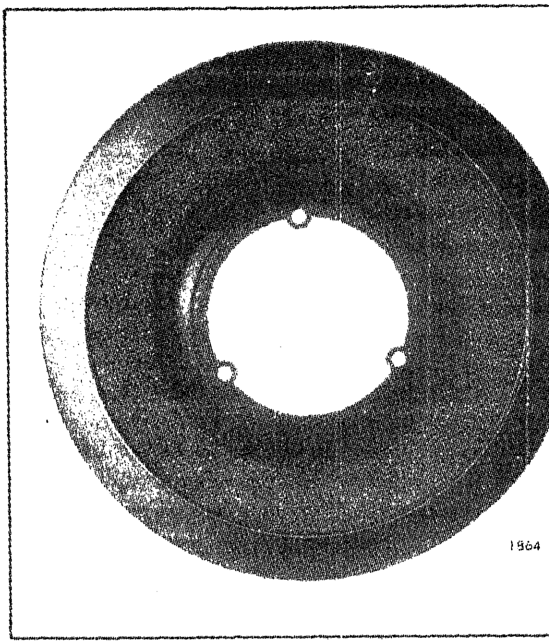


Fig. 11 - Air Cleaner Tray (Clean)

and center tube each time the oil cup is ser there are any indications of plugging, th assembly should be removed from the eng cleaned by soaking and then flushing with cl oil. Allow the unit to drain thoroughly.

8. Place the removable element in the body a Install the body if it was removed from the en servicing.

9. Install the outer cup and baffle assembly. Be cup is tightly secured to the body assembly.

All oil bath air cleaners should be ser operating conditions warrant. At no time shou than 1/2" of "sludge" be allowed to form in cup or the area used for sludge deposit, nor sh oil cup be filled above the oil level mark.

The *United Specialties dry-type air cleaner* s Fig. 12 consists of a body, dust unloader and clamped to a base.

Air is drawn through the cleaner intake pip automatically set into a circular motion. This spinning of the dirty air "throws out" the particles of dust and dirt where they are col

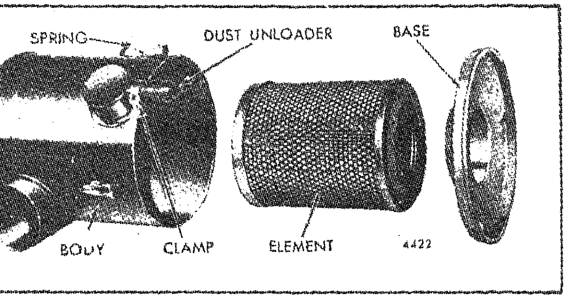


Fig. 12 - United Specialties Dry Type Air Cleaner

sen the clamp screw and check the dust unloader struction or damage.

ock the spring clamps that hold the cleaner body cleaner base which is bolted to the air inlet g. Remove the body and then remove the it from the cleaner base.

e paper pleated air cleaner element can be d as follows:

r a temporary expedient in the field, tap the de or end of the element carefully against the ılm of your hand.

UTION: Do not tap the element against a 'd surface. This could damage the element.

mpressed air can be used when the major ntaminant is dust. The compressed air (not to ceed 100 psi) should be blown through the ement in a direction opposite to the normal air w. Insert the air nozzle inside of the element d gently tap and blow out the dust with air. 'hen cleaning the dust from the outside of the ement, hold the nozzle at least 6″ from the ement.

ash the element if compressed air is not ailable, or when the contaminant is carbon, ot, oily vapor or dirt which cannot be removed th compressed air.

itate the element in warm water containing a n-sudsing detergent.

UTION: Do not use water hotter than your d can stand, solvents, oil, fuel oil or oline.

runs clean to rinse all loosened foreign material from the element. Shake out excess water from the element and allow it to dry thoroughly.

CAUTION: Do not attempt to remove excess water by using compressed air.

4. Inspect the cleaned element with a light bulb after each cleaning for damage or rupture. The slightest break in the element will admit sufficient airborne dirt to cause rapid failure of piston rings. If necessary, replace the element.

5. Inspect the gasket on the end of the element. If the gasket is damaged or missing, replace the element.

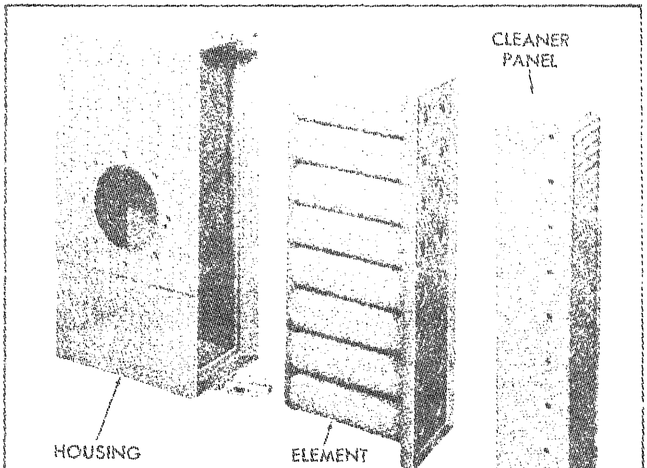
6. Install the element on the base with the gasket side of the element down against the base. Place the body over the element and base and tighten the spring clamps by hand.

7. Replace the element after 10 washings or 1 year of service, whichever comes first, or any time damage is noted.

8. Install the dust unloader and tighten the clamp.

The *Farr dry-type air cleaner* (Fig. 13) is designed to provide highly efficient air filtration under all operating conditions and is not affected by engine speed. The cleaner assembly consists of a cleaner panel with a replaceable impregnated paper filter element.

The cleaner panel and replaceable filter element are held together in a steel housing with fasteners.



The deflector vanes impart a swirling motion to the air entering the air cleaner and centrifuge the dust particles against the walls of the tubes. The dust particles are then carried to the dust bin at the bottom of the cleaner by approximately 10% bleed-off air and are finally discharged into the atmosphere. The cleaner panel is fully effective at either high or low velocities.

The remainder of the air in the cleaner reverses direction and spirals back along the discharge tubes again centrifuging the air. The filtered air then reverses direction again and enters the replaceable filter element through the center portion of the discharge tubes. The air is filtered once more as it passes through the pleats of the impregnated paper element before leaving the outlet port of the cleaner housing.

The cleaner panel tends to be self-cleaning. However, it should be inspected and any accumulated foreign material removed during the periodic replacement of the impregnated paper filter element. Overloading of the paper element will not cause dirt particles to by-pass the filter and enter the engine, but will result in starving the engine for air.

The filter element should be replaced, as operating conditions warrant, as follows:

1. Loosen the wing nuts on the fasteners and swing the retaining bolts away from the cleaner panel.

2. Lift the cleaner panel away from the housing and inspect it. Clean out any accumulated foreign material.

3. Withdraw the paper filter element and discard it.

4. Install a new filter element.

5. Install the cleaner panel and secure it in place with the fasteners.

Air Silencer

The air silencer, used on some marine engines, is bolted to the intake side of the blower housing. The silencer has a perforated steel partition welded in place parallel with the outside faces, enclosing flame-proof, felted cotton waste which serves as a silencer for air entering the blower.

large foreign particles which might seriously d the blower assembly.

Air Box Drains

During normal engine operation, water vapor the air charge, as well as a slight amount of fu lubricating oil fumes, condenses and settles c bottom of the air box. This condensation is re by the air box pressure through air box drain mounted on the side of the cylinder block.

The air box drains must be open at all times. Wi engine running, a periodic check is recommend air flow from the air box drain tubes. I accumulation on the bottom of the air box indic drain tube may be plugged. Such accumulations seen by removing the cylinder block air box co and should be wiped out with rags or blown ou compressed air. Then remove the drain tube connectors from the cylinder block and clean thoroughly.

Some engines are equipped with an air box check valve. Refer to the *Lubrication and Pre Maintenance* section of this manual for s instructions.

Crankcase Ventilation

Harmful vapors which may form within the engi removed from the crankcase, gear train and compartment by a continuous, pressurized vent system.

A slight pressure is maintained within the e crankcase by the seepage of a small amount from the airbox past the piston rings. This air s up through the engine and is drawn off thro crankcase breather.

In-line engines are equipped with a breather ass which is mounted on the rocker cover or the fl housing. The 6V engines incorporate a br assembly mounted inside of the upper engine cover.

The wire mesh pad (element) in the br assemblies should be cleaned if excessive cra pressure is observed. If it is necessary to clea element, remove the breather housing fro flywheel housing (In-line engines) and the

LUBRICATING SYSTEM

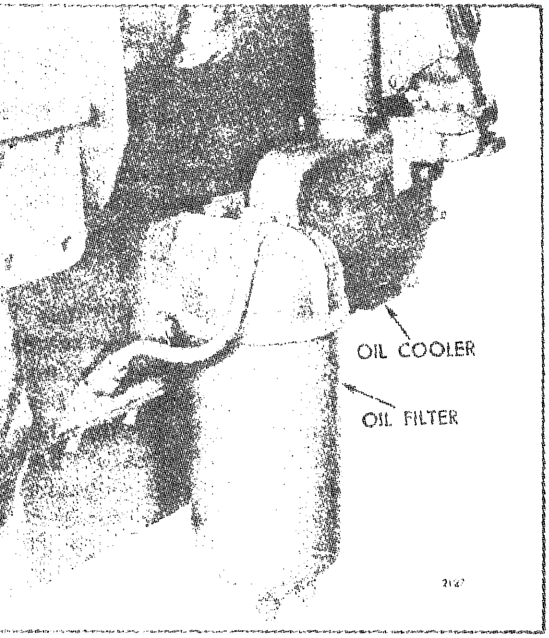


Fig. 14 - Typical In-Line Engine Oil Filter Mounting

ries 53 engine lubricating system, illustrated in 6 and 17, includes an oil intake screen and tube ly, an oil pump, a pressure regulator, a full-flow r or by-pass filter with by-pass valve, and an oil vith a by-pass valve.

iting oil from the pump passes from the lower over through short oil galleries in the cylinder From the block, the oil flows to the full-flow oil hen through the oil cooler (if used) and back e front engine cover and cylinder block oil s for distribution to the various engine gs. The drains from the cylinder head(s) and ngine parts lead back to the oil pan.

ssure is regulated by a pressure relief valve d in the engine front cover. Oil cooler and oil -pass valves prevent the stoppage of oil flow if ems become plugged.

ers

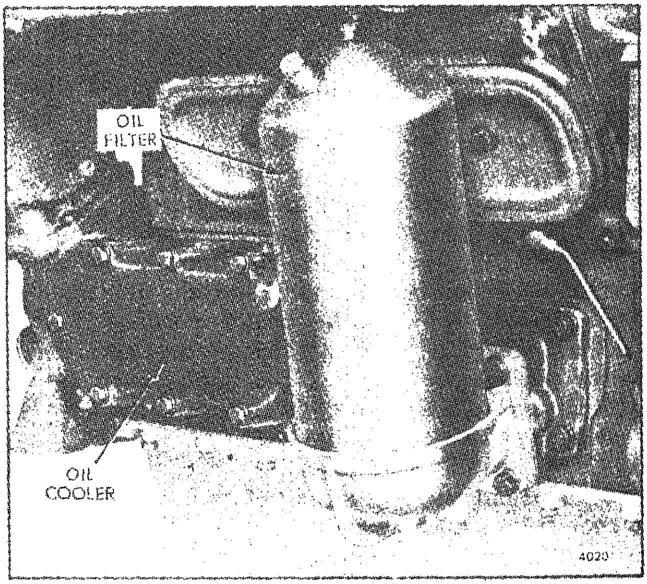


Fig. 15 - Typical V-Type Engine Oil Filter Mounting

full-flow filter that removes the larger foreign particles without restricting the normal flow of oil.

The by-pass filter assembly, when used, continually filters a portion of the lubricating oil that is being bled off the oil gallery when the engine is running. Eventually all of the oil passes through the filter, filtering out minute foreign particles that may be present.

The lubricating oil filter elements should be replaced, each time the engine oil is changed, as follows:

1. Remove the drain plug and drain the oil.

2. The filter shell, element and stud may be detached as an assembly, after removing the center stud from the base. Discard the gasket.

3. Clean the filter base.

4. Discard the used element, wipe out the filter shell and install a new element on the center stud.

5. Place a new gasket in the filter base, position the

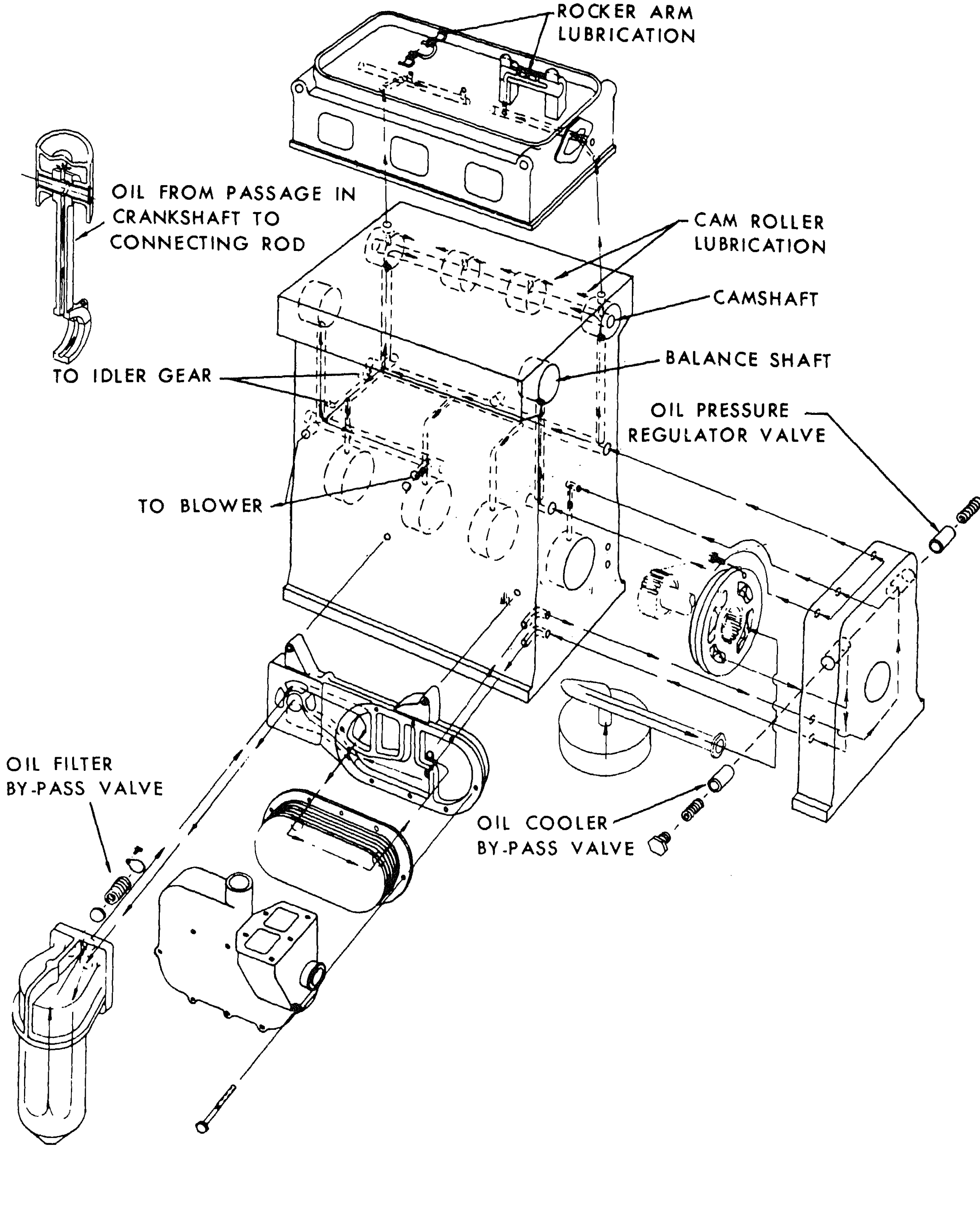


Fig. 16 - Schematic Diagram of Typical In-Line Engine Lubricating System

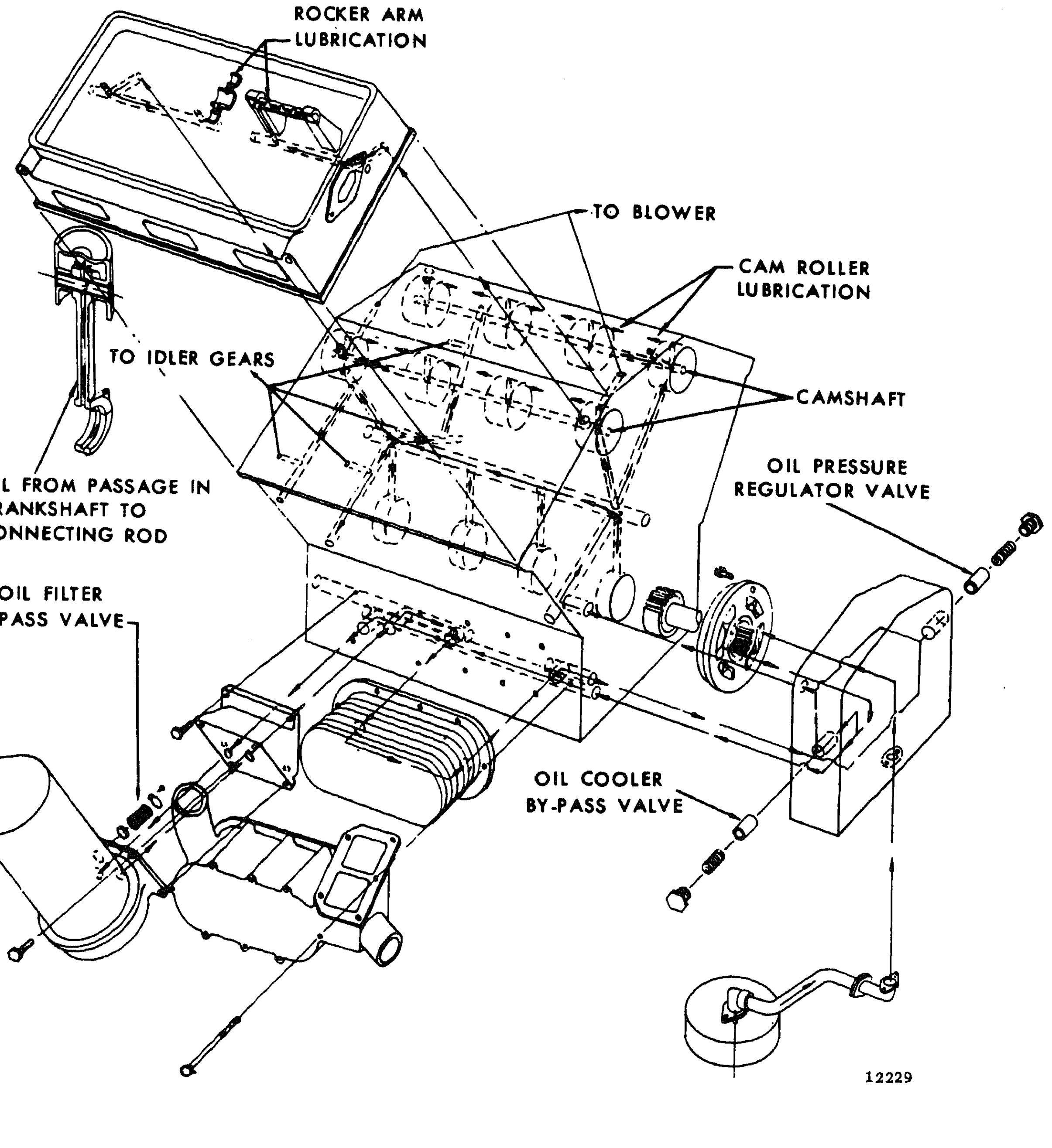


Fig. 17 - Schematic Diagram of Typical 6V Engine Lubricating System

One of three different types of cooling systems is used on a Series 53 engine: radiator and fan, heat exchanger and raw water pump, or keel cooling. A centrifugal type water pump is used to circulate the engine coolant in each system. Each system incorporates thermostats to maintain a normal operating temperature of 160-185°F (71-85°C). Typical engine cooling systems are shown in Figs. 18 and 19.

Radiator Cooling System

The engine coolant is drawn from the bottom of the radiator core by the water pump and is forced through the oil cooler and into the cylinder block. The coolant circulates up through the cylinder block into the cylinder head, then to the water manifold and thermostat housing. From the thermostat housing, the coolant returns to the radiator where it passes d series of tubes and is cooled by the air stream c by the fan.

When starting a cold engine or when the cool below operating temperature, the coolant is rest at the thermostat housing(s) and a by-pass pr water circulation within the engine during the up period.

Heat Exchanger Cooling System

In the heat exchanger cooling system, the cool drawn by the circulating pump from the bottom expansion tank through the engine oil cooler, through the engine the same as in the radiator an system. Upon leaving the thermostat housing coolant either passes through the heat exchange

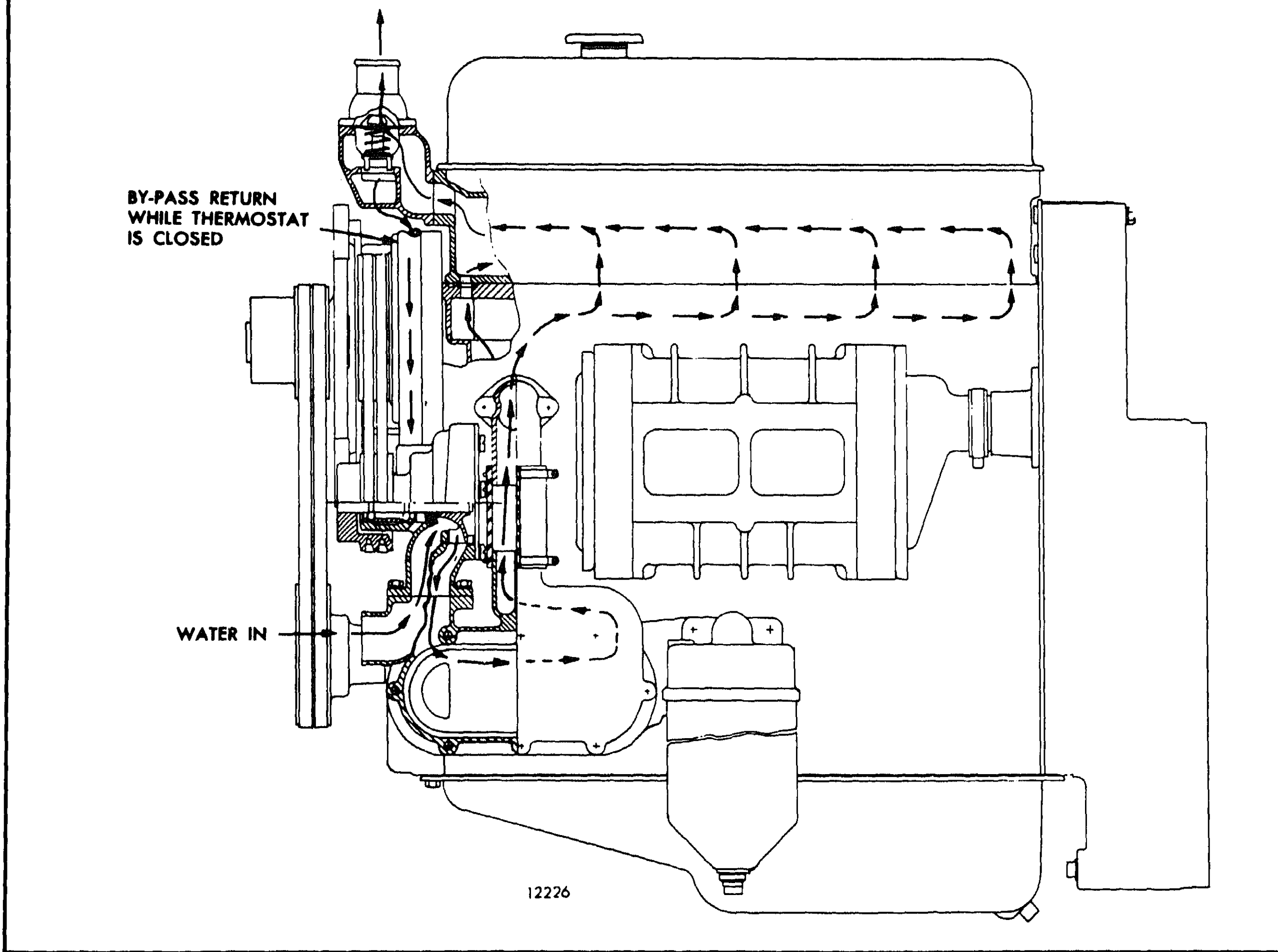


Fig. 18 - Typical Cooling System for In-Line Engines

-passes the heat exchanger and flows directly to water pump, depending on the coolant rature.

passing through the core of the heat exchanger, oolant temperature is lowered by raw water, is drawn by the raw water pump from an e supply. The raw water enters the heat nger at one side and is discharged at the ite side.

rotect the heat exchanger element from lytic action, a zinc electrode is located in both eat exchanger inlet elbow and the raw water inlet elbow and extends into the raw water ge.

The length of time a heat exchanger will function satisfactorily before cleaning will be governed by the kind of coolant used in the engine and the kind of raw water used. Soft water plus a rust inhibitor or a high boiling point type antifreeze should be used as the engine coolant.

When foreign deposits accumulate in the heat exchanger to the extent that cooling efficiency is impaired, such deposits can, in most instances, be removed by circulating a flushing compound through the fresh water circulating system without removing the heat exchanger. If this treatment does not restore the engine's normal cooling characteristics, contact an authorized *Detroit Diesel Allison Service Outlet*.

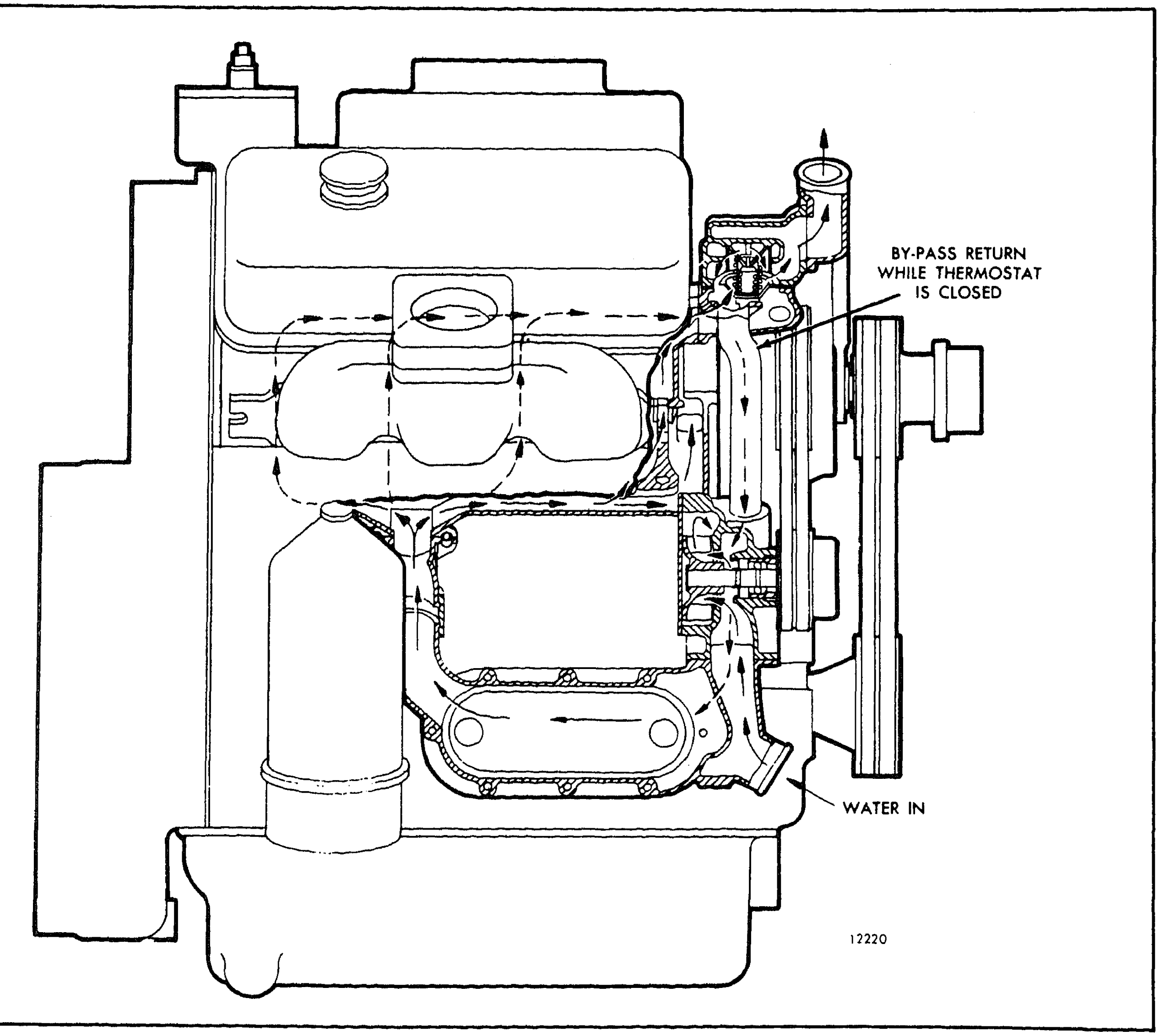


Fig. 19 - Typical Cooling System for V-Type Engine

Keel Cooling System

The keel cooling system is similar to the heat exchanger system, except that the coolant temperature is reduced in the keel cooler. In this system, the coolant is drawn by the circulating pump from the bottom of the expansion tank through the engine oil cooler. From the cooler the flow is the same as i other systems. Upon leaving the thermostat hou the coolant is by-passed directly to the bottom o expansion tank until the engine operating tem ture, controlled by the thermostat, is reached. A engine temperature increases, the coolant is direct the keel cooler, where the temperature of the coola reduced before flowing back to the expansion tank

ENGINE COOLING SYSTEM MAINTENANCE

Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from the component parts such as exhaust valves, cylinder liners and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil-to-water oil cooler.

For the recommended coolant, refer to *Engine Coolant*.

Cooling System Capacity

The capacity of the basic engine cooling system (cylinder block, head, thermostat housing and oil cooler housing) is shown in Table 1.

To obtain the complete amount of coolant in the cooling system of an engine, the additional capacity of the radiator, hoses, etc. must be added to the capacity of the basic engine. The capacity of radiators and related equipment should be obtained from the equipment supplier.

Fill Cooling System

Before starting an engine, close all of the drain cocks and fill the cooling system completely. If the unit has a raw water pump, it should be primed, since operation without water may cause impeller failure.

COOLING SYSTEM CAPACITY CHART (BASIC ENGINE)		
ENGINE	CAPACITY	
	Quarts	Litres
3-53	8	8
4-53	9	9
6V-53	14	13

TABLE 1

Start the engine and, after normal opera temperature has been reached, allowing the coola expand to its maximum, check the coolant level. coolant level should be within 2″ of the top o filler neck.

Should a daily loss of coolant be observed, and are no apparent leaks, there is a possibility of leaking past the cylinder head water seal rings int cooling system. The presence of air or gases in cooling system may be detected by connecti rubber tube from the overflow pipe to a container. Bubbles in the water in the container d engine operation will indicate this leakage. An method for observing air in the cooling system inserting a transparent tube in the water outlet lin

Drain Cooling System

The engine coolant is drained by opening the cyli block and radiator (heat exchanger) drain cocks removing the cooling system filler cap. Removal o filler cap permits air to enter the cooling passages the coolant to drain completely from the system.

Drain cocks or plugs are located on each side o 4-53 and 6V cylinder blocks. The 3-53 cylinder has a drain cock or plug located on the side o block opposite the oil cooler.

> **IMPORTANT:** Drain cocks or plugs on both side of the engine must be opened to drain th engine completely.

In addition to the drains on the cylinder blocks, th line engines have a drain cock located on the bo of the oil cooler housing. The V-type engines hav drain cocks that must be opened when drainin system. Radiators, etc., that do not have a drain are drained through the oil cooler housing drain.

To insure that all of the coolant is drained comp from an engine, all cooling system drains shou opened. Should any entrapped water in the cyl block or radiator freeze, it will expand and may damage. When freezing weather is expected, dra

all of the drain cocks open until refilling the cooling system.

The exhaust manifolds of marine engines are cooled by the same coolant used in the engine. Whenever the engine cooling system is drained, each exhaust manifold drain cock, located on the bottom near the exhaust outlet, must be opened.

Raw water pumps are drained by loosening the cover attaching screws. It may be necessary to tap the raw water pump cover gently to loosen it. After the water has been removed, tighten the screws.

Flushing

The cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, preparing the cooling system for a new solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the engine.

2. Refill the cooling system with soft clean water. If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for 15 minutes to circulate the water thoroughly.

4. Drain the cooling system completely.

5. Refill the system with the solution required for the coming season.

Cooling System Cleaners

If the engine overheats and the fan belt tension and water level are satisfactory, clean and flush the entire cooling system. Remove scale formation by using a quality de-scaling solvent. Immediately after using the solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the de-scaling solvent be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse-flush before filling the cooling system.

pump should be removed and the radiator an[cut off] reverse-flushed separately to prevent dirt a[cut off] deposits clogging the radiator tubes or bein[cut off] through the pump. Reverse-flushing is acco[cut off] by hot water, under air pressure, being forced [cut off] the cooling system in a direction opposite [cut off] normal flow of coolant, loosening and forci[cut off] deposits out.

The radiator is reverse-flushed as follows:

1. Remove the radiator inlet and outlet ho[cut off] replace the radiator cap.

2. Attach a hose at the top of the radiator [cut off] water away from the engine.

3. Attach a hose to the bottom of the radia[cut off] insert a flushing gun in the hose.

4. Connect the water hose of the gun to th[cut off] outlet and the air hose to the compressed air o[cut off]

5. Turn on the water and, when the radiato[cut off] turn on the air in short blasts, allowing the ra[cut off] fill between air blasts.

> **CAUTION:** Apply air gradually. Do not [cut off] more than 30 psi (207 kPa) air pressure. [cut off] great a pressure may rupture a radiator tub[cut off]

6. Continue flushing until only clean water is [cut off] from the radiator.

The cylinder block and cylinder head water [cut off] are reverse-flushed as follows:

1. Remove the thermostat and the water pump[cut off]

2. Attach a hose to the water inlet of the cylind[cut off] to drain the water away from the engine.

3. Attach a hose to the water outlet at the to[cut off] cylinder block and insert the flushing gun in th[cut off]

4. Turn on the water and, when the water ja[cut off] filled, turn on the air in short blasts, allo[cut off] engine to fill with water between air blasts.

5. Continue flushing until the water from th[cut off] runs clean.

If scale deposits in the radiator cannot be rem[cut off]

Miscellaneous Cooling System Checks

n addition to the above cleaning procedures, the other omponents of the cooling system should be checked eriodically to keep the engine operating at peak fficiency. The thermostat and the radiator pressure ap should be checked and replaced, if found lefective. The cooling system hoses should be nspected and any hose that feels abnormally hard or oft should be replaced immediately.

Also, check the hose clamps to make sure they are ight. All external leaks should be corrected as soon as letected. The fan belt must be adjusted to provide the oroper tension, and the fan shroud must be tight gainst the radiator core to prevent re-circulation of ir which may lower cooling efficiency.

Water Pump

A centrifugal-type water pump is mounted on top of he engine oil cooler housing, either on the right-hand or left-hand side of the engine, depending upon the ngine model and rotation. It circulates the coolant hrough the cooling system.

The pump is belt driven, by either the camshaft or balance shaft (In-line engines) or by one of the amshafts (V-type engines).

An impeller is pressed onto one end of the water pump shaft, and a water pump drive pulley is pressed onto the opposite end. The pump shaft is supported on a sealed double-row combination radial and thrust ball bearing. Coolant is prevented from creeping along the shaft toward the bearing by a seal. The shaft and bearing constitute an assembly and are serviced as uch, since the shaft serves as the inner race of the ball bearing.

The sealed water pump shaft ball bearing is filled with ubricant when assembled. No further lubrication is equired.

Contact an authorized *Detroit Diesel Allison Service Outlet* if more information is needed.

Raw Water Pump

The raw water pump (Figs. 20 and 21) is a positive displacement pump, used for circulating raw water hrough the heat exchanger to lower the temperature of the engine coolant. It is driven by a coupling from he end of the camshaft.

Seal failure is readily noticed by a flow of water visible at the openings in the raw water pump housing, ocated between the pump mounting flange and the

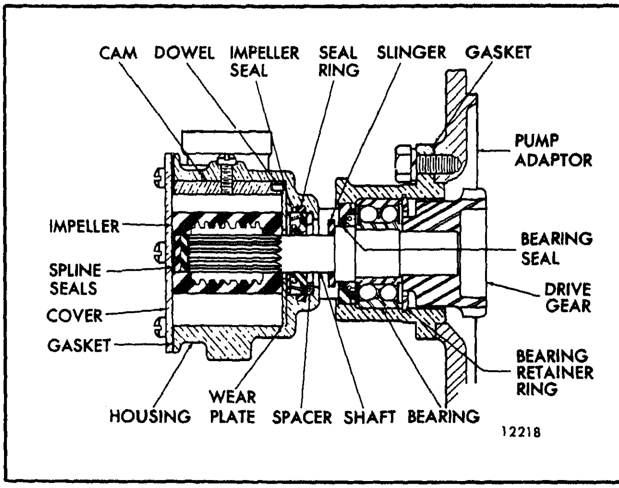


Fig. 20 - Raw Water Pump Used on In-Line Engine

inlet and outlet ports. These openings must remai open at all times.

The impeller, cam and wear plate assembly, and wate seal assembly may be serviced without removing th pump from the engine as outlined below.

1. Remove the cover and gasket.

2. Note the position of the impeller blades to aid i the reassembly. Then grasp a blade on each side of th impeller with pliers and pull the impeller off of th shaft.

3. The neoprene spline seal(s) can be removed fron the impeller by pushing a screw driver through th impeller from the open end.

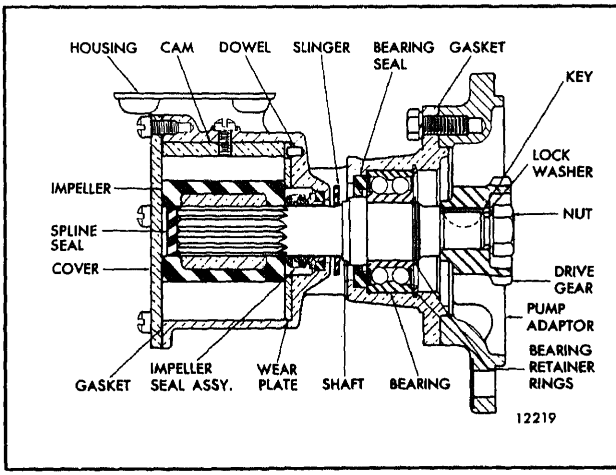


Fig. 21 - Raw Water Pump Used on V-Type Engine

CAUTION: If the impeller is reuseable, exercise care to prevent damage to the splined surfaces.

4. Remove the cam retaining screw and withdraw the cam and wear plate assembly.

5. Remove the seal assembly from the pump used on a V-type engine by inserting two wires with hooked ends between the pump housing and seal with the hooks over the edge of the carbon seal. Remove the seal seat and gasket in the same way.

6. The seal may be removed from the pump used on the In-line engine by drilling two holes in the seal case and placing metal screws in the holes so that they may be grasped and pulled with pliers. Then remove the rubber seal ring.

7. Clean and inspect the impeller, cam and wear plate assembly and water seal. The impeller must have a good bond between the neoprene and the metal. If the impeller blades are damaged, worn or have taken a permanent set, replace the impeller. Reverse the wear plate if it is worn excessively and remove any burrs. Replace the seal, if necessary.

8. Install the seal assembly in the pump used on a V-type engine as follows:

a. If the seal seat and gasket were removed, place the gasket and seal seat over the shaft and press them into position in the seal cavity.

b. Place the seal ring securely in the ferrule, and with the carbon seal and washer correctly positioned against the ferrule, slide the ferrule over the shaft and against the seal seat. Use care to ensure that the seal ring is contained within the ferrule so that it grips the shaft.

c. Install the flat washer and then the marcel washer.

A new seal may be installed in the pump used In-Line engine by placing the rubber seal ring groove, starting the seal (with the lip facin impeller cavity) over the shaft and tapping i place against the seal spacer.

9. Install the cam and wear plate assembly.

NOTE: The wear plate is round and is dowel to the cam. The wear plate must be install with the cam in the pump housing as assembly.

10. Apply a non-hardening sealant to the retaining screw and the hole in the pump bo prevent any leakage. Then hold the cam wit tapped hole aligned and secure it with the screw.

11. Compress the impeller blades to clear the cam and press the impeller on the splined shaf blades must be correctly positioned to follo direction of rotation.

12. Install the neoprene splined seal(s) in the b the impeller.

13. Turn the impeller several revolutions in the n direction of rotation to position the blades.

14. Affix a new gasket and install the pump cover

The Jabsco raw water pump is equipped w synthetic rubber impeller. Since synthetic rubbe its elasticity at low temperatures, impellers ma natural rubber should be installed when it is nec to pump raw water that has a temperature below (4 °C).

The natural rubber impeller can be identified stripe of green paint between two of the im blades.

ENGINE EQUIPMENT

INSTRUMENT PANEL, INSTRUMENTS AND CONTROLS

The instruments (Fig. 1) generally required in the operation of a diesel engine consist of an oil pressure gage, a water temperature gage, an ammeter and a mechanical tachometer. Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starter switch, an engine stop knob, an emergency stop knob and, on certain applications, the engine hand throttle.

Torqmatic converters are equipped with an oil pressure gage and, in some instances, an oil temperature gage. These instruments are mounted on a separate panel.

Oil Pressure Gage

The oil pressure gage registers the pressure of the lubricating oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed under *Running* in the *Engine Operating Instructions,* the engine should be stopped and the cause of low oil pressure determined and corrected before the engine is started again.

Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

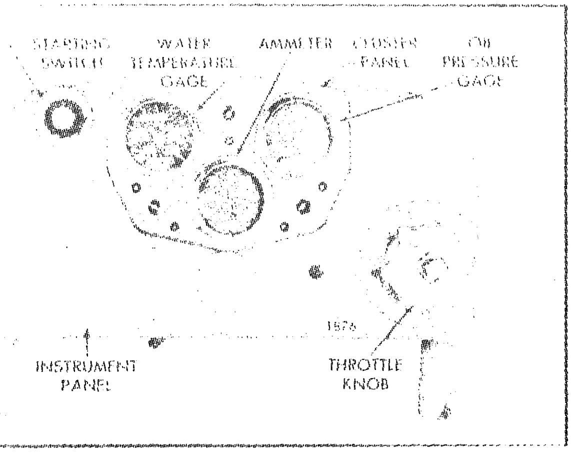


Fig. 1 - Typical Instrument Panel

Ammeter

An ammeter is incorporated into the electrical circui to show the current flow to and from the battery. Afte starting the engine, the ammeter should register a hig charge rate at rated engine speed. This is the rate o charge received by the battery to replenish the curren used to start the engine. As the engine continues t operate, the ammeter should show a decline in charg rate to the battery. The ammeter will not show zer charge rate since the regulator voltage is set highe than the battery voltage. The small current registere prevents rapid brush wear in the battery-chargin alternator. If lights or other electrical equipment ar connected into the circuit, the ammeter will sho discharge when these items are operating or th engine speed is reduced.

Tachometer

The tachometer is driven by the engine and register the speed of the engine in revolutions per minut (rpm).

Engine Starting Motor Switch

The starting switch is mounted on the instrumen panel with the contact button extending through th front face of the panel. The switch is used to energiz the starting motor. As soon as the engine starts, releas the switch.

Stop Knob

A stop knob is used on most applications to shut th engine down. When stopping an engine, the spee should be reduced to idle and the engine allowed t operate at idle for a few minutes to permit the coolan to reduce the temperature of the engine's movin parts. Then the stop knob should be pulled and hel until the engine stops. Pulling on the stop kno manually places the injector racks in the "no-fuel position. The stop knob should be returned to i original position after the engine stops.

Emergency Stop Knob

In an emergency or if after pulling the stop knob, th

may be pulled to stop the engine. The emergency stop knob, when pulled, will trip the air shut-off valve located between the air inlet housing and the blower and shut off the air supply to the engine. Lack of air will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed back in after the engine stops so the air shut-off valve can be opened for restarting after the malfunction h corrected.

Throttle Control

The engine throttle is connected to the governo control shaft through linkage. Movement of th control shaft changes the speed setting of the g and thus the engine speed.

MANUAL SHUT-DOWN SYSTEM

The manually operated emergency engine shut-down levice, mounted in the air inlet housing, is used to top the engine in the event an abnormal condition hould arise. If the engine continues to run after the ngine throttle is placed in the *no-fuel* position, or if ombustible liquids or gases are accidentally introluced into the combustion chamber causing overpeeding of the engine, the shut-down device will revent damage to the engine by cutting off the air upply and thus stopping the engine.

The shut-down device consists of an air shut-off valv mounted in the air inlet housing which is retained i the open position by a latch. A cable assembly is use to remotely trip the latch. Pulling the emergency shut down knob all the way out will stop the engine. Afte the engine stops, the emergency shut-down knob mus be pushed all the way in and the air shut-off valv manually reset before the engine can be started again.

AUTOMATIC MECHANICAL SHUT-DOWN SYSTEM

The automatic mechanical shut-down system illusrated in Fig. 2 is designed to stop the engine if there s a loss of oil pressure, loss of engine coolant, overheating of the engine coolant, or overspeeding of he engine. Engine oil pressure is utilized to activate he components of the system.

A coolant temperature-sensing valve and an adaptor and copper plug assembly are mounted on the exhaust manifold outlet. The power element of the temperature-sensing valve is placed against one end of th copper plug, and the other end of the plug extend into the exhaust manifold. Engine coolant is directe through the adaptor and passes over the powe element of the valve. Engine oil, under pressure, i directed through a restricted fitting to the temperature sensing valve and to an oil pressure actuated bellow located on the air inlet housing.

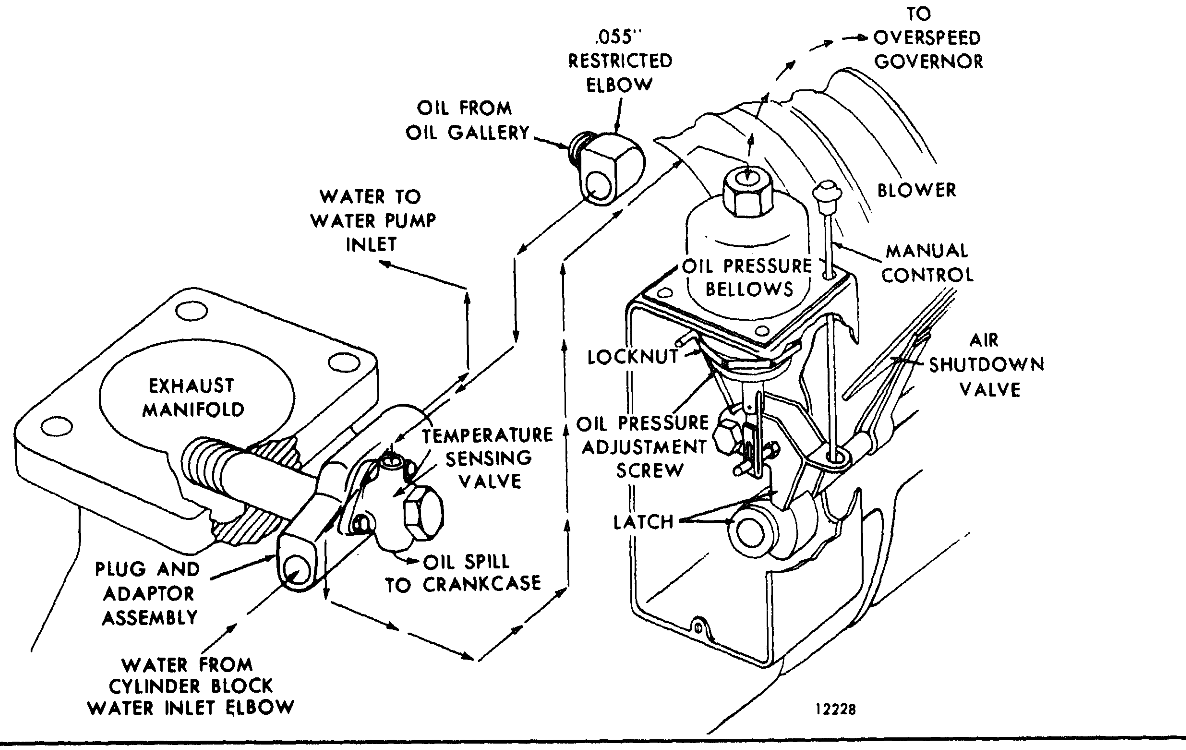


Fig. 2 · Mechanical Shut-Down System Schematically Illustrated

The pressure of the oil entering the bellows overcomes the tension of the bellows spring and permits the latch to retain the air shut-off valve in the open position. If the oil pressure drops below a predetermined value, the spring in the bellows will release the latch and permit the air shut-off valve to close and thus stop the engine.

The overspeed governor, used on certain applications, consists of a valve actuated by a set of spring-loaded weights. Engine oil is supplied to the valve through a connection in the oil line between the bellows and the temperature-sensing valve. An outlet in the governor valve is connected to the engine oil sump. Whenever the engine speed exceeds the overspeed governor setting, the valve (actuated by the governor weights) is moved from its seat and permits the oil to flow to the engine sump. This decreases the oil pressure to the bellows, thus actuating the shut-down mechanism and stopping the engine.

A restricted fitting, which will permit a drop in oil pressure great enough to actuate the shut-down mechanism, is required in the oil line between the cylinder block oil gallery and the shut-down sensing devices.

To be sure the protective system will function properly if an abnormal engine condition occurs, have the system checked periodically by your local *Detroit Diesel Allison Service Outlet.*

Also make sure the air shut-off valves close each time the engine is shut down.

Operation

To start an engine equipped with a mechanical down system, first manually open the air shut-off and then press the engine starting switch. As so the engine starts, the starting switch may be rel but the air shut-off valve must be held in the position until the engine oil pressure inc sufficiently to permit the bellows to retain the la the open position.

During operation, if the engine oil pressure below the setting of the pressure sensitive bellow spring within the bellows will release the latc permit the air shut-off valve to close, thus stoppi engine.

If the engine coolant overheats, the temper sensing valve will open and permit the oil protective system to flow to the engine crankcas resulting decrease in oil pressure will actuate the down mechanism and stop the engine. Also engine loses its coolant, the copper plug will be up by the hot exhaust gases passing over it and the temperature-sensing valve to open and actua shut-down mechanism.

Whenever the engine speed exceeds the ove governor (if used) setting, the oil in the line fl the sump, resulting in a decrease in oil pressur oil pressure bellows then releases the latch and p the air shut-off valve to close.

When an engine is stopped by the action of the down system, the engine cannot be started agai the particular device which actuated the shut mechanism has returned to its normal positio *abnormal condition which caused the engine to sto be corrected before attempting to start it again.*

AUTOMATIC ELECTRICAL SHUT-DOWN SYSTEM

The automatic electrical shut-down system shown in Fig. 3 protects the engine against a loss of coolant, overheating of the coolant, loss of oil pressure, or overspeeding. In the event one of the foregoing conditions arises, a switch will close the electrical circuit and energize the solenoid switch, causing the shut-down solenoid to release the air shut-down latch and stop the engine.

Operation

The electrical circuit is de-energized under normal operating conditions. When the engine is started, the oil pressure switch opens when the oil pressure reaches approximately 10 psi (69 kPa) and the fuel oil pressure switch closes at approximately 20 psi (138 kPa pressure. The water temperature switch remains

If the oil pressure drops below 10 psi (69 kPa), pressure switch will close the circuit and energi shut-down solenoid. This will activate the shu mechanism and stop the engine.

A loss of coolant or an increase in coolant tempe to approximately 203 °F (95 °C) will close the c in the water temperature switch, thus closi electrical circuit and activating the shut mechanism.

The water temperature switch consists of a te ture-sensing valve and a micro-switch. The contacts a copper plug (heat probe) which exten

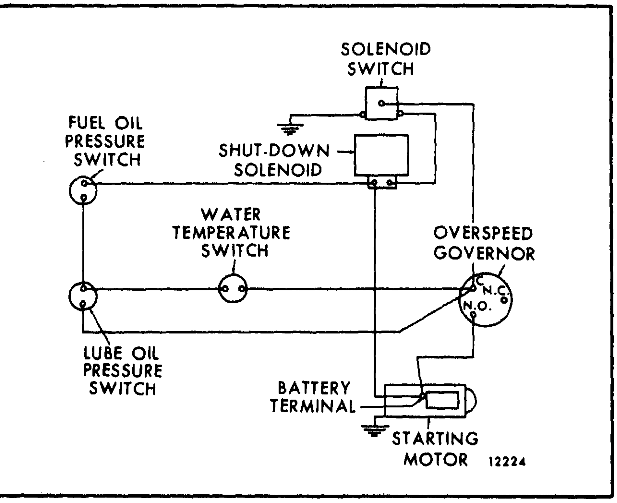


Fig. 3 - Automatic Electrical Shut-Down System Diagram

ne exhaust manifold outlet. Engine water is directed ver the power element of the valve and should the ater temperature exceed approximately 203° F 95° C), the valve will close the contacts in the micro-vitch and energize the shut-down circuit. If a loss of ater occurs, the heat of the exhaust gases will be ansmitted through the copper plug to the tempera-ure-sensing valve and cause the shut-down circuit to e activated.

 the engine speed exceeds the high speed setting of ne overspeed governor, the governor switch will close nd activate the shut-down mechanism.

Vhen the engine is shut-down, the decrease in speed ill open the governor switch, and the decrease in oil nd fuel pressures will close the oil pressure switch and pen the fuel pressure switch, thus de-energizing the ircuit.

he cause of the abnormal conditions must then be etermined and corrected before the engine is started gain. Also, the air shut-off valve must be manually eset in the open position before the engine can be arted.

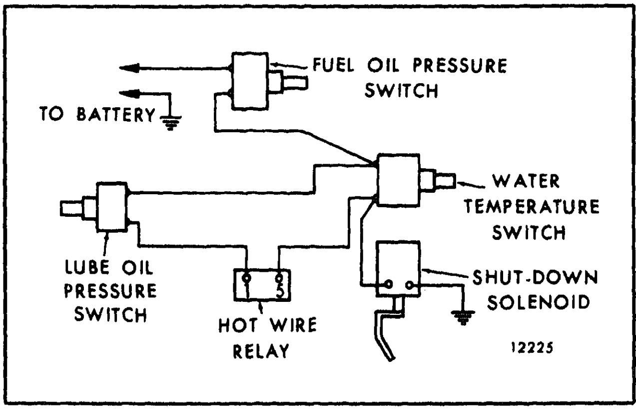


Fig. 4 - Automatic Electrical Shut-Down System Incorporating Hot Wire Relay

Some engines are equipped with an electrically operated automatic shut-down system which incorporates a hot wire relay (Fig. 4).

Since the fuel pressure builds up rapidly, the fuel oil pressure switch could close before the lubricating oil pressure switch opens, and effect a shut-down of the engine. The hot wire relay, however, delays the closing of the fuel oil pressure switch for several seconds to enable the lubricating oil pressure to build up and open the oil pressure switch contacts.

When the lubricating oil pressure falls below 10 ± 2 psi (69 ± 14 kPa), the contacts in the oil pressure switch used in this system will close and current will flow through the hot wire relay to the solenoid. The few seconds required to heat the hot wire relay provides sufficient delay to avoid an engine shut-down when low oil pressure is caused by a temporary condition such as an air bubble or a temporary overlap in the operation of the oil pressure switch and the fuel oil pressure switch when starting or stopping the engine.

The water temperature switch, which remains open during normal engine operation, is installed in the side of the thermostat housing. The switch contacts close when the water temperature reaches approximately 205° F (96° C) and activate the shut-down solenoid.

ALARM SYSTEM

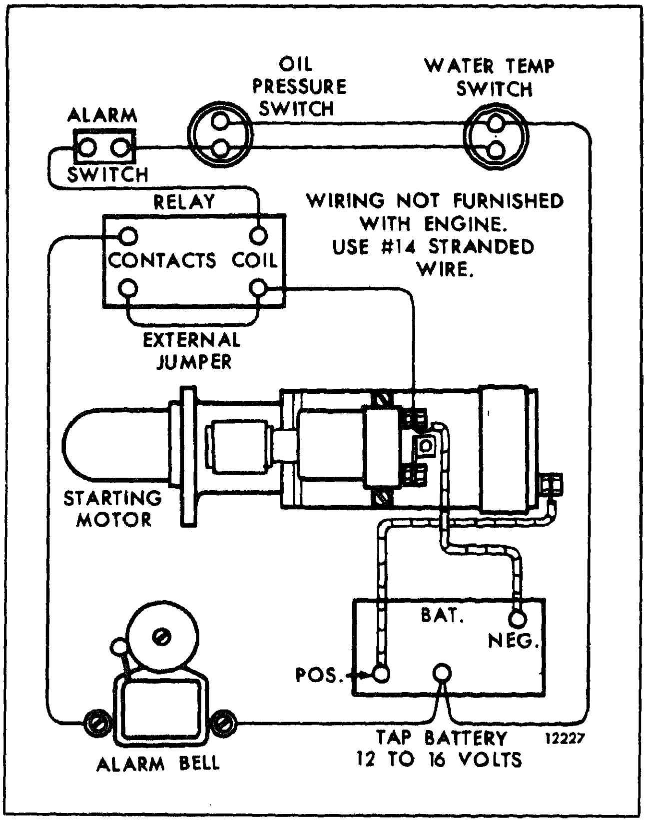


Fig. 5 - Alarm System Wiring Diagram

The alarm system shown in Fig. 5 is simi
automatic electrical shut-down system, bu
warning bell in place of the air shut-off valve
The bell warns the engine operator if th
coolant overheats or the oil pressure drops
safe operating limit.

When the engine is started and the oil p
sufficient to open the oil pressure switch
(opening pressure is stamped on the switch
alarm switch must be turned on manually
system in operation. The water temperature
normally open. Should the engine coolan
205° ± 5°F (96° ± –15°C), the water te
switch will close the electrical circuit and
alarm bell. Likewise, if the oil pressure dr
the setting of the oil pressure switch, the s
close and cause the bell to ring. The bell wil
to ring until the engine operator turns
switch off. The alarm switch must also be
before a routine stop since the decreasing oi
will close the oil pressure switch and cause
ring.

If the alarm bell rings during engine opera
the engine immediately and determine the
the abnormal condition. *Make the necessary*
before starting the engine again.

STARTING SYSTEMS

ELECTRICAL STARTING SYSTEM

The electrical system on the engine generally consists of a battery-charging alternator, a starting motor, voltage regulator, storage battery, starter switch and the necessary wiring. Additional electrical equipment may be installed on the engine unit at the option of the owner.

Starting Motor

The starting motor has a Sprag overrunning clutch. Pressing the starting switch engages the starting motor pinion with the teeth of the flywheel ring gear and energizes the starting motor. The starting motor drives the pinion and rotates the crankshaft. When the engine begins to operate, the Sprag clutch permits the pinion to overrun on its shaft, until the starting switch is released, and prevents overspeeding the starting motor.

Starter Switch

To start the engine, a switch is used to energize the starting motor. Release the switch immediately after the engine starts.

Alternator

The battery-charging alternator provides the electrical current required to maintain the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

Regulator

A voltage regulator is introduced into the electrical system to regulate the voltage and current output of the battery-charging alternator and to maintain a fully charged storage battery.

Storage Battery

The lead-acid storage battery is an electroch device for converting chemical energy into ele energy.

The battery has three major functions:

1. It provides a source of electrical power for st the engine.

2. It acts as a stabilizer to the voltage in the ele system.

3. It can, for a limited time, furnish current wh electrical demands of the unit exceed the output alternator.

The battery is a perishable item which re periodic servicing. A properly cared for batter give long and trouble-free service.

1. Check the level of the electrolyte regularly water if necessary, but do not overfill. Overfillin cause poor performance or early failure.

2. Keep the top of the battery clean. When nec wash with a baking soda solution and rinse with water. Do not allow the soda solution to enter the

3. Inspect the cables, clamps and hold-down b regularly. Clean and re-apply a light coating of when needed. Replace corroded, damaged parts.

4. Use the standard, quick in-the-unit battery the regular service test to check battery condition

5. Check the electrical system if the battery be discharged repeatedly.

If the engine is to be stored for more than 30 remove the battery. The battery should be store cool, dry place. Keep the battery fully charge check the level of the electrolyte regularly.

The *Lubrication and Preventive Maintenance* sect this manual covers the servicing of the starting and alternator.

Consult an authorized *Detroit Diesel Allison S Outlet* for information regarding the electrical sy

The Hydrostarter System schematically illustrated in Fig. 6 is a complete hydraulic system for starting internal combustion engines. The system is automatically recharged after each start, and can be manually recharged. The starting potential remains during long periods of inactivity, and continuous exposure to hot or cold climates has no detrimental effect upon the Hydrostarter system. Also, the Hydrostarter torque for a given pressure remains substantially the same regardless of the ambient temperature.

The Hydrostarter system consists of a reservoir, an engine-driven charging pump, a hand pump, a piston type accumulator, a starting motor and connecting hoses and fittings.

Operation

Hydraulic fluid flows by gravity, or a slight vacuum, from the reservoir to either the engine-driven pump or the hand pump inlet. Fluid discharging from either pump outlet at high pressure flows into the accumulator and is stored at 3250 psi (22 383 kPa) under the pressure of compressed nitrogen gas.

When the starter is engaged with the engine flywheel ring gear and the control valve is opened, fluic pressure is forced out of the accumulator, expanding nitrogen gas, and flows into the s motor which rapidly accelerates the engine to cranking speed. The used fluid returns directly reservoir from the starter.

The engine-driven charging pump runs conti during engine operation and automatically re the accumulator. When the required press attained in the accumulator, a valve within th body opens and the fluid discharged by the p by-passed to the reservoir. The system can down and the pressure in the accumulator maintained.

The precharge pressure of the accumulator pressure of the nitrogen gas with whi accumulator is initially charged. This pressure checked before the system pressure is raised initial engine start. To check the precharge p open the relief valve, on the side of the hand approximately 1/2 turn, allowing the pressure return to zero. Close the relief valve and pump strokes on the hand pump. The gage should rapid pressure rise from zero to the precharge pressure, where it will remain change for several additional strokes of the pun

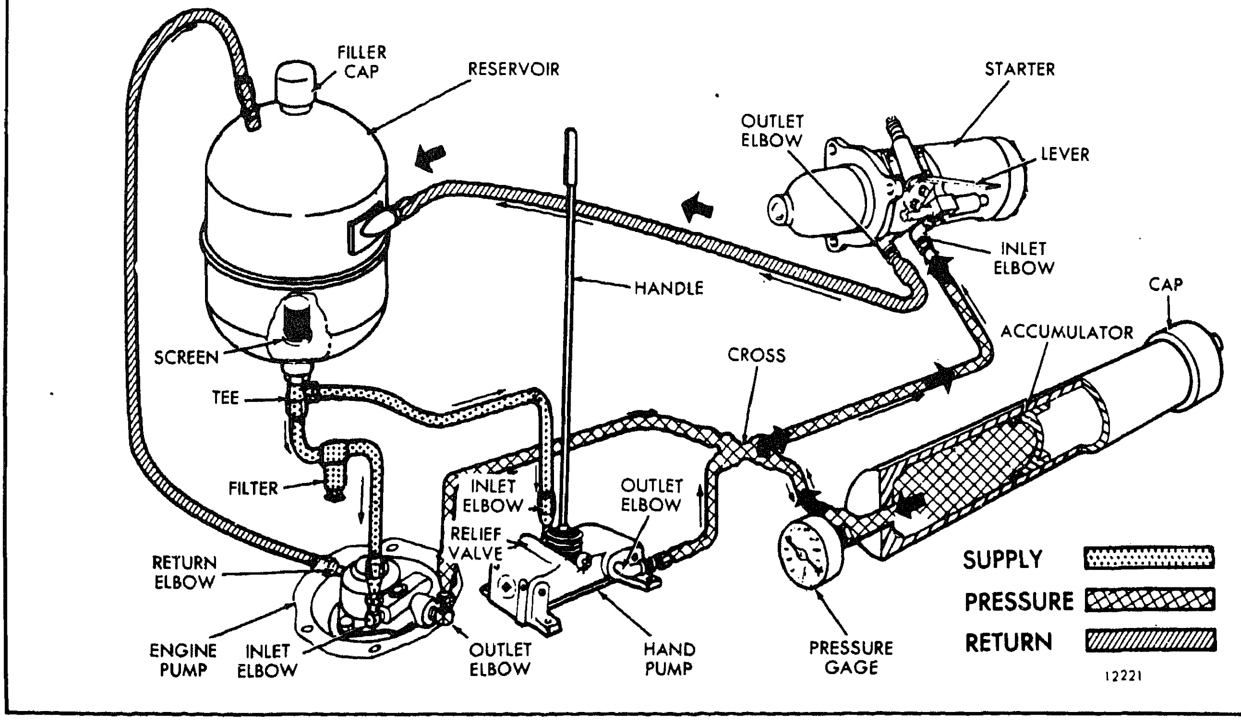


Fig. 6 - Schematic Diagram of Hydrostarter System Showing Oil Flow

Initial Engine Start

Use the hand pump to raise the accumulator pressure. An accumulator pressure of 1500 psi (10 335 kPa) when the ambient temperature is above 40 °F (4 °C) will provide adequate cranking to start the engine. Between 40 °F (4 °C) and 0 °F (–18 °C), 2500 psi (17 225 kPa) should be sufficient. Below 0 °F (–18 °C), the accumulator should be charged to the maximum recommended pressure. Although the Hydrostarter cranks the engine faster than other starting systems, starting aids should be used in cold weather.

NOTE: Use the priming pump to make sure the filters, lines, manifolds and injectors are full of fuel before attempting to start the engine.

For ambient temperatures below 40 °F (4 °C), use a fluid starting aid. Add the starting fluid just prior to moving the Hydrostarter lever and during the cranking cycle as required. Do not wait to add the starting fluid after the engine is turning over, otherwise the accumulator charge may be used up before the engine can start. In this case, the accumulator charge must be replaced with the hand pump.

With the engine controls set for start (throttle at least half-open), push the Hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve quickly when the engine starts, to conserve the accumulator pressure and prevent excessive overrunning of the starter drive clutch assembly.

Three different basic types of flywheel ring gears are used; no chamfer, Bendix chamfer, or Dyer chamfer on the gear teeth. Some difficulty may be encountered in engaging the starter pinion with the Dyer chamfered ring gears. When this happens, it is necessary to disengage and re-engage until the starter pinion is cammed in the opposite direction enough to allow the teeth to mesh.

Remote Control System

The Hydrostarter remote control system (Fig. 7) consists of a master cylinder, a pedal, a lever arm, two springs and a flexible hose. It is an independent hydraulic system using diesel fuel oil as a hydraulic fluid to actuate the Hydrostarter control valve by

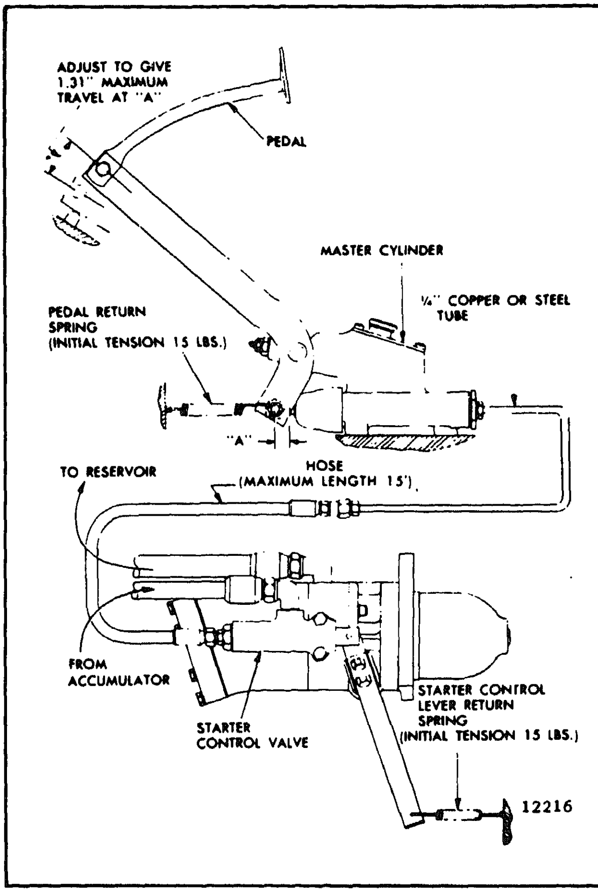


Fig. 7 - Hydrostarter Remote Control System

flywheel ring gear. Release the pedal as soon as engine starts.

The Hydrostarter motor is equipped with a cont valve that incorporates a threaded valve housing p with a 1/8″-27 tapped hole in the center installation of the flexible hose. A 1/8″-27 pipe p is installed when the remote control system is not us

Springs are used to return the master cylinder pe and the Hydrostarter control lever to the off position

Filling

Remove the filler cap from the reservoir and ad sufficient quantity of hydraulic fluid (a mixture of 7 diesel fuel and 25% SAE 10 or 30 lubricating oil) fill the system.

litres) capacity reservoir, add approximately 8
8 litres) of hydraulic fluid, 10 quarts (9 litres)
quart (11 litres) reservoir, 14 quarts (13 litres)
quart (15 litres) reservoir or 21 quarts (20
a 23 quart (22 litres) reservoir.

E: When the accumulator is charged to psi (20 670 kPa) and all hoses are filled, e should be enough hydraulic fluid remain- in the reservoir to completely cover the n in the bottom of the reservoir.

ss valve is located on the inlet side of the hand Loosen the lock nut and rotate this valve mately one turn counterclockwise with a screw Operate the hand pump for 12 to 15 complete Do not pump too rapidly. Close the by-pass ghtly and tighten the lock nut.

the starter control lever to engage the pinion e flywheel and open the control valve. While the lever in this position, operate the hand ntil the starter has turned several revolutions. e control valve. Loosen the swivel hose fitting ischarge side of the engine-driven pump about ns. Operate the hand pump to force air out begins to appear at the loose fitting. Tighten el hose fitting and pressurize the system with d pump sufficiently to start the engine.

orm the initial starting instructions under *tion for Starting Engine First Time*. Then, with ine running at least 1500 rpm, purge the driven pump of air. Break the hose connection ischarge side of the engine driven-pump until tream of oil is discharged from the pump. the hose to the pump and alternately loosen nten the swivel fitting on the discharge hose e oil leaking out, when the fitting is loose, to be free of air bubbles. Tighten the fitting and observe the pressure gage. The pressure rise rapidly to the accumulator precharge (1250 psi or 10 413 kPa at 70°F or 21°C), rease slowly, reaching 2900 to 3300 psi (19 981 7 kPa).

the pressure has stabilized near 3000 psi kPa), examine all of the high pressure hoses, ons and fittings for leaks.

the open reservoir filler spout. An occasional spurt of oil may be emitted from the hose prior to by-passing. When the by-pass valve opens, a full and continuous stream of oil will flow from the hose. Reconnect the hose to the reservoir and install the filler cap.

5. Fill the reservoir to the proper level.

The Hydrostarter remote control system may be purged of air as follows:

1. Fill the master cylinder with fuel oil.

2. Loosen the hose fitting at the Hydrostarter control valve.

3. Actuate the master cylinder pedal until all of the air is discharged from the system and a solid stream of fuel oil is being discharged with each stroke.

NOTE: Replenish the fluid in the master cylinder as required during the purging operation.

4. Tighten the hose fitting and check for leaks.

LUBRICATION AND PREVENTIVE MAINTENANCE

Inspect the system periodically for leaks. Primarily, examine the high pressure hoses, connections, fittings and the control valve on the starter. Make certain that the oil level in the reservoir is sufficient to completely cover the screen at the bottom of the tank. Make this check after the accumulator is charged and the engine driven pump is by-passing oil to the reservoir.

Every 2000 hours, or as conditions warrant, drain the reservoir and remove the screen. Flush out the reservoir and clean the screen and filler cap. Then reinstall the screen.

Remove the bowl and element from the filter in the engine-driven pump supply hose. Wash the bowl and element in clean fuel oil and reassemble the filter.

Release the pressure and drain the remaining hydraulic fluid from the system by disconnecting the hoses from the Hydrostarter components. Then reconnect all of the hydraulic hoses.

CAUTION: The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible

Lubrication

Remove the Hydrostarter from the engine every 2000 hours for lubrication. Before removing the Hydrostarter, release the pressure in the system by means of the relief valve in the hand pump. Then remove the three bolts which retain the starting motor to the flywheel housing. Remove the starting motor without disconnecting the hydraulic oil hoses. This will prevent dirt and air from entering the hydraulic system.

Apply a good quality, lightweight grease on the drive clutch pinion to make sure the clutch will slide freely while compressing the spring. Also apply grease to the fingers of the clutch fork and on the spool of the clutch yoke engaged by the fork. This lubrication period may be reduced or lengthened according to the severity of service.

Remove the pipe plug from the starting motor drive housing and saturate the shaft oil wick with engine oil. Then reinstall the plug.

After lubricating, install the starting motor on the flywheel housing and recharge the accumulator with the hand pump.

On engines equipped with a hydraulic remote control system, lubricate the shaft in the master cylinder through the pressure grease fitting every 2000 hours.

Cold Weather Operation

Occasionally, when an engine is operated in regions of very low temperatures, the starter drive clutch assembly may slip when the starter is engaged. If the clutch slips, proceed as follows:

1. Release the oil pressure in the system by opening the relief valve in the hand pump.

> **CAUTION:** The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible injury to personnel or equipment.

2. Disconnect the hydraulic hoses from the star motor.

3. Remove the three retaining bolts and lock was and withdraw the starting motor from the flyw housing.

4. Disassemble the starting motor.

5. Wash the Hydrostarter drive clutch assembly clean fuel oil to remove the old lubricant.

6. When the clutch is free, apply SAE 5W lubrica oil.

7. Reassemble the starting motor and reinstall it the engine. Then attach a tag to the starter noting lubricant used in the clutch.

8. Recharge the accumulator with the hand pump.

Marine Application

In addition to the normal Hydrostarter lubrication maintenance instructions, the following special pre tions must be taken for marine installations or o cases where equipment is subject to salt spray and or other corrosive atmospheres:

1. Clean all exposed surfaces and apply a coat of z chromate primer, followed by a coat of suitable pa

2. Apply a liberal coating of Lubriplate, type 130- or equivalent, to the following surfaces.

   a. The exposed end of the starter control valve around the control shaft where it passes thro the clutch housing.

   b. The exposed ends of the hand pump cam pin.

3. Operate all of the moving parts and check protective paint and lubrication every week.

Consult an authorized *Detroit Diesel Allison Se Outlet* for any information relating to the Hydrost system.

COLD WEATHER STARTING AIDS

In a diesel engine, the fuel injected into the combustion chamber is ignited by the heat of the air compressed into the cylinder. However, when starting an engine in extremely cold weather, a large part of

necessary to use an air heater or a starting flui assist ignition of the fuel.

the heat of compression to ignite the fuel-air mixture.

FLUID STARTING AID

The fluid starting aid (Fig. 8) is designed to inject a highly volatile fluid into the air intake system at low ambient temperatures to assist in igniting the fuel oil injected. The fluid is contained in suitable capsules to facilitate handling.

The starting aid consists of a cylindrical capsule container with a screw cap, inside of which a sliding piercing shaft operates. A tube leads from the capsule container to a hand operated pump and another tube leads to the atomizing nozzle threaded into a tapped hole in the air inlet housing.

The capsule container should be mounted in a vertical position and away from any heat.

Start the engine, using the fluid starting aid, as follows:

1. Remove the threaded cap and insert a fluid capsule in an upright position within the container.

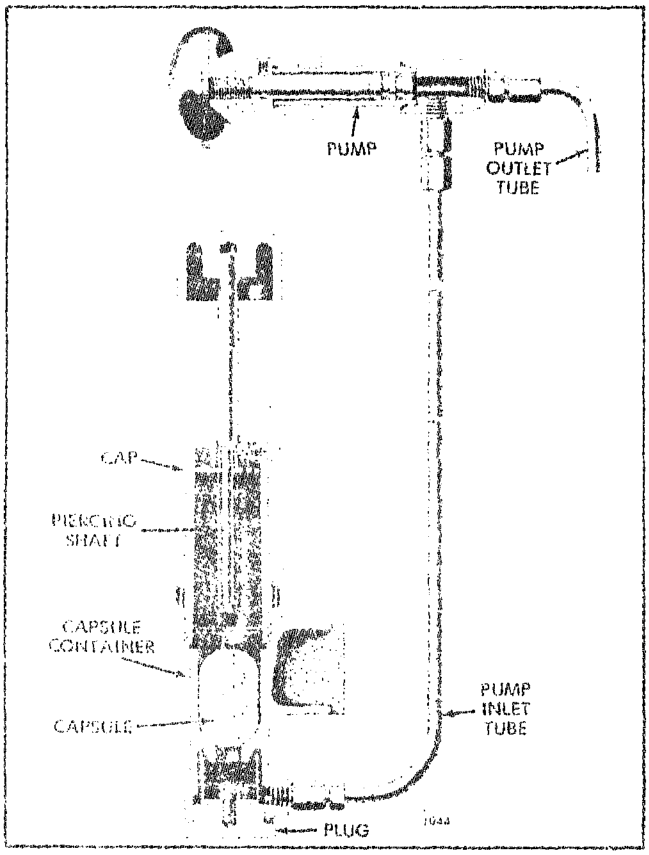


Fig. 8 - Typical Fluid Starting Aid

CAUTION: The starting fluid is toxic and inflammable. Use caution when handling.

2. Pull the piercing shaft all the way out and install and tighten the cap on the container.

3. Push the piercing shaft all the way down. This will rupture the capsule and fill the container with the starting fluid.

4. Move the engine throttle to the maximum speed position.

5. Engage the starter and at the same time pull the pump plunger all the way out. Push the plunger in slowly, forcing the starting fluid through the atomizing nozzle into the air intake. Continue to push the pump in until the engine starts. If the plunger is not all the way in when the engine starts, push it in slowly until it locks in the IN position.

6. Unscrew the cap and remove the capsule. *Do not leave the empty capsule in the container.*

7. Replace the cap on the capsule container and make sure the piercing shaft is all the way down.

Service

The cold weather fluid starting aid will require very little service. Replace the piston seal packing if the pump leaks. If there is an excessive resistance to pumping, the nozzle may be plugged. Remove the nozzle and clean it.

PRESSURIZED CYLINDER STARTING AID

Start the engine during cold weather, using the "Quick Start" starting aid system (Fig. 9) as follows:

1. Press the engine starter button.

2. Pull out the "Quick Start" knob for one or two seconds, then release it.

3. Repeat the procedure if the engine does not start on the first attempt.

CAUTION: Do not crank the engine more than 30 seconds at a time when using an electric starting motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

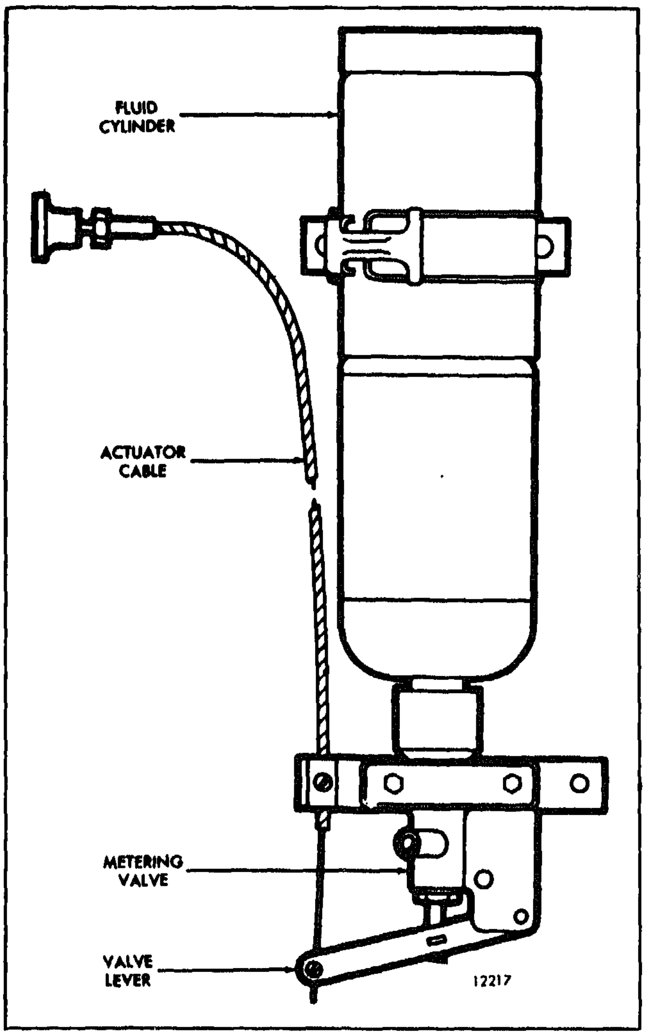


Fig. 9 - Quick-Start Assembly

Service

Periodically perform the following service items to assure good performance:

1. Remove the fluid cylinder and lubricate the valve around the pusher pin under the gasket with a few drops of oil.

2. Lubricate the actuator cable.

3. Actuate the valve with the cable to distribute the oil on the cable and allow the oil to run down through the valve.

4. Remove any dirt from the orifice by removing the air inlet housing fitting, the orifice block and the screen. Then blow air through the orifice end only.

5. Assemble and tighten the air inlet housing fitting to the actuator valve and tube.

6. Check for leakage of fluid (fogging) on the outside of the engine air inlet housing by actuating the starting aid while the engine is stopped. If fogging occurs, disassemble and retighten the air inlet housing fitting to the housing.

> **CAUTION:** Do not actuate the starting aid more than once with the engine stopped. *Over-loading the engine air box with this high volatile fluid could result in a minor explosion.*

7. Check the fluid cylinder for hand tightness.

GOVERNORS

Horsepower requirements of an engine may vary continually due to the fluctuating loads; therefore, some means must be provided to control the amount of fuel required to hold the engine speed reasonably constant during such load fluctuations. To accomplish this control, one of three types of governors is used on the engines. Installations requiring maximum and minimum speed control, together with manually controlled intermediate speeds, ordinarily use a *limiting speed* mechanical governor. Applications requiring a near constant engine speed under varying load conditions, that may be changed by the operator, are equipped with a *variable speed* mechanical governor. The *hydraulic governor* is used where uniform engine speed is required under varying load conditions with a minimum speed droop.

Lubrication

The mechanical governors are lubricated by oil splash from the engine gear train. Oil entering the governor is directed by the revolving governor weights to the various moving parts requiring lubrication.

The hydraulic governor is lubricated by oil under pressure from the engine.

Service

Governor difficulties are usually indicated by speed variations of the engine. However, speed fluctuations are not necessarily caused by the governor and, therefore, when improper speed variations become evident, the unit should be checked for excessive load, misfiring or bind in the governor operating linkage. If none of these conditions are contributing to faulty governor operation, contact an authorized *Detroit Diesel Allison Service Outlet*.

TRANSMISSIONS

POWER TAKE-OFF ASSEMBLIES

The front and rear power take-off units are basically similar in design, varying in clutch size to meet the requirements of a particular application. The power take-off unit is attached to either an adaptor (front power take-off) or the engine flywheel housing (rear power take-off).

Clutch Adjustment

These instructions refer to field adjustment for clutch facing wear. Frequency of adjustment depends upon the amount and nature of the load. To ensure a long clutch facing life and the best performance, the clutch should be adjusted before slippage occurs.

When the clutch is properly adjusted, a heavy pressure is required at the outer end of the hand lever to move the throwout linkage to the "over center" or locked position.

Adjust the clutch as follows:

1. Disengage the clutch with the hand lever.

2. Remove the inspection hole cover to expose the clutch adjusting ring. Rotate the clutch, if necessary, to bring the adjusting ring lock within reach.

3. Remove the clutch adjusting ring spring lock screw and lock from the inner clutch pressure plate and adjusting ring. Then, while holding the clutch drive shaft to prevent the clutch from turning, turn the clutch adjusting ring counterclockwise as shown in Fig. 10 and tighten the clutch until the desired pressure on the outer end of the hand lever, or at the

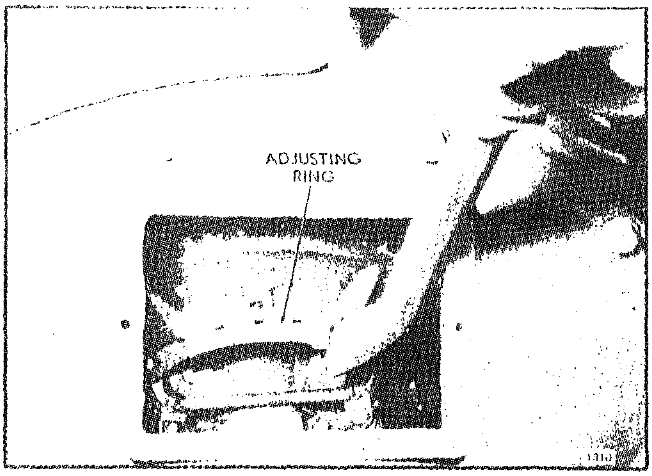


Fig. 10 - Adjusting Clutch

Clutch Diameter	Hand Lever Length	Pressure		Torque	
		PSI	kPa	lb-ft	Nm
8"	15 1/2"	55	379	56-63	76-85
10"	15 1/2"	80	552	87-94	113-127
*11 1/2"	15 3/8"	100	689	129	175
11 1/2"	20"	105	724	112-120	152-163

*Twin Disc Clutch

TABLE 1

clutch release shaft (Fig. 11), is obtained as shown in Table 1.

When properly adjusted, the approximate pressure required at the outer end of the hand lever to engage the various diameter clutches is shown in the table. These specifications apply only with the hand lever which is furnished with the power take-off.

A suitable spring scale may be used to check the pounds pressure required to engage the clutch. However, a more accurate method of checking the clutch adjustment is with a torque wrench as shown in Fig. 11.

To fabricate an adaptor, saw the serrated end off of a clutch hand lever and weld a 1-1/8" nut (across the hex) on it as shown in Fig. 11. Then saw a slot through the nut.

When checking the clutch adjustment with a torque wrench, engage the clutch slowly and note the amount of torque immediately before the clutch engages (goes over center). The specified torque is shown in Table 1.

> **CAUTION:** The thrust load on the bronze clutch release bearing should be kept at an absolute minimum. Therefore, the hand lever should be positioned on the shaft as near the 12 o'clock or 6 o'clock position as possible. The 9 and 3 o'clock positions are to be avoided.

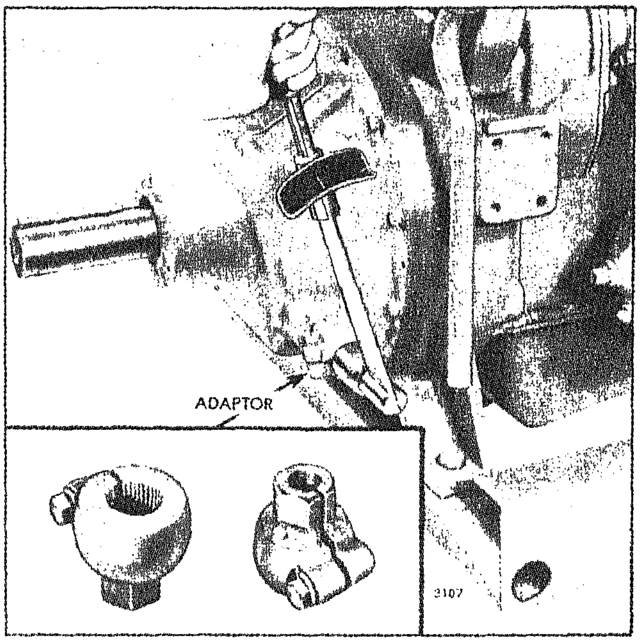


Fig. 11 - Checking Clutch Adjustment with a Torque Wrench and Adaptor

Make a final clutch adjustment with the engine running as follows:

1. Start the engine and operate it at idling speed (approximately 500 rpm) with the clutch disengaged. The speed will be sufficient to move the segments out to the operating position.

2. Check the pressure required to engage the clutch. The engagement pressure should be the same as that following the adjustment. If the clutch engages at a lower pressure, the adjustment was probably made against the unworn portion of the facing.

3. Stop the engine and readjust the clutch, making sure all disc segments are properly positioned. Install the inspection hole cover.

TORQMATIC CONVERTERS

The Torqmatic converter is a self contained unit which transfers and multiplies the torque of the prime mover. This unit transmits the power through the action of oil instead of through gears and in addition to multiplying the torque also acts as a fluid coupling between the engine and the equipment to be powered. The converter will automatically adjust the output torque to load requirements.

There are various combinations of Torqmatic converters with features such as: an automotive or industrial flange on the shaft, a hydraulically operated lock-up clutch, a manual input disconnect clutch, and an accessory drive for either a governor or tachometer.

Check the oil level daily. If the converter is equipped with an input disconnect clutch, additional checks and service will be necessary daily or at intervals determined by the type of operation.

Adjust the disconnect clutches as outlined under power take-off clutch adjustment.

Contact an authorized *Detroit Diesel Allison Service Outlet* for service on Torqmatic converters.

WARNER MARINE GEAR

The Warner hydraulic marine gear assembly consists of a hydraulically operated multiple disc clutch in combination with a hydraulically actuated reversing gear train, an oil pressure regulator, an oil sump independent of the engine oil system and an oil cooler mounted on the engine.

Oil pressure for the operation of the marine gear is provided by an oil pump incorporated within the gear housing and driven continuously while the engine is running. The oil is delivered under pressure from the pump to a combination marine gear control valve and pressure regulator valve.

The pressure regulator valve maintains constant pressure over a wide speed range and the control valve directs the oil under pressure to either the forward or reverse piston cylinder. The operating oil pressure range for the marine gear at operating speed is 120 to 140 psi (827 to 965 kPa) and the maximum oil temperature is 225 °F (107 °C). Minimum oil pressure is 100 psi (689 kPa) at idle speed (600 rpm).

Shifting from forward to reverse drive through neutral may be made at any speed; however, it is advisable to shift at low speeds, below 1000 engine rpm, to avoid damage to the engine, reverse gear or shaft.

The marine reverse and reduction gear is lubricated by pressure and splash. The quantity of oil in the marine gear will vary with the inclination of the engine and must be properly maintained to the *full* mark on the dipstick to ensure satisfactory operation.

It is recommended that vessels utilizing a marine gear have a suitable locking device or brake to prevent rotation of the propeller shaft when the vessel is not under direct propulsion. If the marine gear is not in operation and the forward motion of the vessel causes the propeller shaft to rotate, lubricating oil will not be circulated through the gear because the oil pump is not in operation. Overheating and damage to the marine gear may result unless rotation of the propeller shaft is prevented.

Consult an authorized *Detroit Diesel Allison Service Outlet* for major repairs or reconditioning of the marine gear.

OPERATING INSTRUCTIONS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow these instructions. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

> **NOTE:** When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart.*

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped.

Remove the filler cap and fill the cooling system with clean, soft water or a protective solution consisting of high boiling point type antifreeze, if the engine will be exposed to freezing temperatures. Refer to *Engine Coolant.* Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

Use a quality rust inhibitor if only water is used in the cooling system.

Close the vents, if used, after filling the cooling system.

On marine installations, prime the raw water cooling system and open any sea cocks in the raw water pump intake line. Prime the raw water pump by removing the pipe plug or electrode provided in the pump outlet elbow and pour water in the pump.

> **CAUTION:** Failure to prime the raw water pump may result in damage to the pump impeller.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 25 psi (172 kPa) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use *heavy-duty* lubricating oil as specified under *Lubricating Oil Specifications.* Then remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the full mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy-duty* lubricating oil as specified. Then pre-lubricate the upper engine parts by removing the valve rocker covers and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Turbocharger

Disconnect the turbocharger oil inlet line and pour approximately one pint of clean engine oil in the line, thus making sure the bearings are lubricated for the initial start. Reconnect the oil line.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with clean engine oil. *Do not overfill.*

Transmission

Fill the transmission case, marine gear or torque converter supply tank to the proper level with the lubricant specified under *Lubrication and Preventive Maintenance.*

Fuel System

Fill the fuel tank with the fuel specified under *Diesel Fuel Oil Specifications.*

If the unit is equipped with a fuel valve, it must be opened.

To ensure prompt starting, fill the fuel system between the pump and the fuel return manifold with fuel. If the engine has been out of service for a considerable length of time, prime the filter between the fuel pump and the injectors. The filter may be primed by removing the plug in the top of the filter cover and slowly filling the filter with fuel.

In addition to the above, on an engine equipped with a Hydrostarter, use a priming pump to make sure the fuel lines and the injectors are full of fuel before attempting to start the engine.

NOTE: The fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance.*

Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

NOTE: When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Generator Set

Where applicable, fill the generator end bearing housing with the same lubricating oil as used in the engine.

A generator set should be connected and grounded in accordance with the applicable local electrical codes.

CAUTION: The base of a generator set must be grounded.

Clutch

Disengage the clutch, if the unit is so equipped.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart.*

If a manual or an automatic shut-down system is incorporated in the unit, the control must be set in the open position before starting the engine.

The blower will be seriously damaged if operated with the air shut-off valve in the closed position.

Starting at air temperatures below 40°F (4°C) requires the use of a cold weather starting aid. See *Cold Weather Starting.*

The instructions for the use of a cold weather fluid starting aid will vary dependent on the type being used. Reference should be made to these instructions before attempting a cold weather start.

CAUTION: Starting fluid used in capsules is highly inflammable, toxic and possesses anesthetic properties.

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the speed control lever at part throttle, then bring it back to the desired no-load speed. In addition, on mechanical governors, make sure the stop lever on the governor cover is in the *run* position. Then press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

CAUTION: To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

Initial Engine Start (Hydrostarter)

Ambient Temperature	Pressure Gage Reading
Above 40°F (4°C)	1500 PSI (10 335 kPa)
40°F to 0°F (4°C to −18°C)	2500 PSI (17 225 kPa)
Below 0°F (−18°C)	3300 PSI (22 737 kPa)

Table 1

An engine equipped with a Hydrostarter may be started as follows:

Raise the Hydrostarter accumulator pressure with the hand pump until the gage reads as indicated in Table 1.

Set the engine controls for starting with the throttle at least half open.

> **NOTE:** During cold weather add starting fluid at the same time the Hydrostarter motor lever is moved. Do not wait to add the fluid after the engine is turning over.

Push the Hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve . Close the valve as soon as the engine starts to conserve the accumulator pressure and to avoid excessive over-running of the starter drive clutch assembly.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. The minimum oil pressure should be at least 18 psi (124 kPa) at 1200 rpm. The oil pressure at normal operating speed should be 40-60 psi (276-414 kPa).

Warm-Up

Run the engine at part throttle and no-load for approximately five minutes, allowing it to warm-up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

Clutch

Do not engage the clutch at engine speeds over 1000 rpm.

Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

Engine Temperature

Normal engine coolant temperature is 160-185°F (71-85°C).

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain back into the crankcase for approximately twenty minutes and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy duty* lubricating oil specified under *Lubricating Oil Specifications.*

Cooling System

Remove the radiator or heat exchanger tank cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or a high boiling point type antifreeze (refer to *Engine Coolant).*

Marine Gear

Check the marine gear oil pressure. The operating oil pressure range for the marine gear at operating speed is 120 to 160 psi (827 to 1103 kPa) and minimum oil pressure is 100 psi (689 kPa) at idle speed (600 rpm).

Turbocharger

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

> **NOTE:** When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Normal Stopping

1. Release the load and decrease the engine speed. Put all shift levers in the *neutral* position.

2. Allow the engine to run at half speed or slower with no load for a short time, then move the stop lever to *stop* to shut down the engine.

Emergency Stopping

If the engine does not stop after using the normal stopping procedure, pull the "Emergency Stop" knob all the way out. This control cuts off the air to the engine. Do not try to restart again until the cause for the malfunction has been found and corrected.

> **CAUTION:** The emergency shut-down system should never be used except in an emergency. Use of the emergency shut-down can cause oil to be sucked past the oil seals and into the blower housing.

The air shut-off valve, located on the blower air inlet housing, must be reset by hand and the "Emergency Stop" knob pushed in before the engine is ready to start again.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Exhaust System

Drain the condensation from the exhaust line or silencer.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open. Open the raw water drains of a heat exchanger cooling system.

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately 20 minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy-duty* lubricating oil specified under *Lubricating Oil Specifications.*

Transmission

Check and, if necessary, replenish the oil supply in the transmission.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to *Lubrication and Preventive Maintenance* and perform all of the daily maintenance operations. Also perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which became apparent to the operator during the last run.

ALTERNATING CURRENT POWER GENERATOR SET OPERATING INSTRUCTIONS

These instructions cover the fundamental procedures for operating an alternating current power generator set (Fig. 1). The operator should read these instructions before attempting to operate the generator set.

Never operate a generator set for a short (15 minute) interval - the engine will not reach normal operating temperature in so short a period.

Avoid operating the set for extended periods at no-load.

Ideally, operate the set for one hour with at least 40% load (generator rating).

When a test must be made with a line load of less than 40% of the generator rating, add a supplementary load.

Connect the supplementary load to the load terminals of the control cabinet circuit breaker so that the generator can be "loaded" whenever the breaker is closed.

Make certain that the supplementary load is such that it can be controlled to permit a reduction in the load should a normal load increase occur while the set is operating. Locate the supplementary load outside the engine room, if desirable, to provide adequate cooling.

Loading the generator set to 40% of the generator rating and operating it for one-hour intervals will bring the engine and generator to normal operating temperatures and circulate the lubricants properly. Abnormal amounts of moisture, carbon and sludge are due primarily to low internal operating temperatures which are much less likely to occur when the set is tested properly.

PREPARATION FOR STARTING

Before attempting to start a new or an overhauled engine or an engine which has been in storage, perform all of the operations listed under *Preparation for Starting Engine First Time.* Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart.*

In addition to the *Engine Operating Instructions,* the

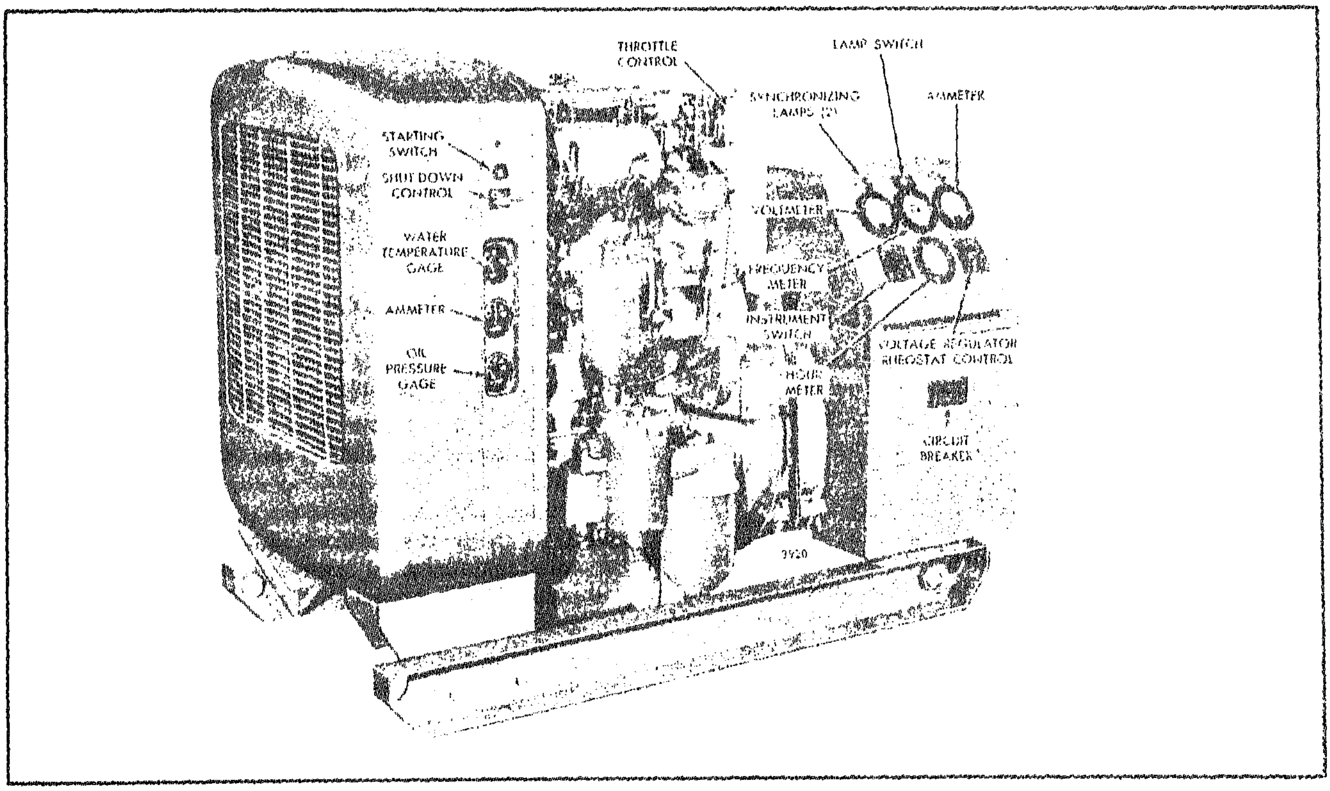


Fig. 1 - Location of Controls on Power Generator Set

following instructions also apply when operating an alternating current power generator set.

1. Before the first start, check the generator main bearing oil reservoir. If necessary, add sufficient lubricating oil, of the same grade as used in the engine crankcase, to bring it to the proper level on the sight gage.

2. Check the interior of the generator for dust or moisture. Blow out dust with low pressure air (25 psi or 172 kPa maximum). If there is moisture on the interior of the generator, it must be dried before the set is started. Refer to the appropriate Delco Products Maintenance bulletin.

3. The air shut-off valve located in the air inlet housing must be in the open or reset position.

4. Refer to Fig. 1 and place the circuit breaker in the **off** position.

5. If the generator set is equipped with synchronizing lamps, place the lamp switch in the **off** position.

6. Turn the voltage regulator rheostat knob counter-clockwise to its lower limit.

7. Make sure the power generator set has been cleared of all tools or other objects which might interfere with its operation.

STARTING

If the generator set is located in a closed space, start the ventilating fan or open the doors and windows, as weather permits, to supply ample air to the engine.

The engine may require the use of a cold weather starting aid if the ambient temperature is below 40° F (4° C). Refer to *Cold Weather Starting Aids.*

Press the throttle button and turn the throttle control (Fig. 1) counterclockwise to a position midway between **run** and **stop.** Then press the starting switch firmly.

If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

> **CAUTION:** To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is rotating.

RUNNING

Observe the engine oil pressure gage immediately after starting the engine. If there is no oil pressure indicated within 10 to 15 seconds, stop the engine and check the engine lubricating system.

If the oil pressure is observed to be normal, increase the throttle setting to cause the engine to run at its synchronous speed.

PREPARING GENERATOR FOR LOAD

After the engine is warmed up (or the oil pressure has stabilized) prepare the generator set for load as follows:

1. Bring the engine up to the rated speed.

2. Turn the instrument switch to the desired position.

3. Turn the voltage regulator rheostat knob slowly in a clockwise direction to raise the voltage, while watching the voltmeter, until the desired voltage is attained.

4. If the generator set is equipped with a frequency meter, adjust the engine speed with the vernier throttle knob until the desired frequency is indicated on the meter.

5. Make sure all power lines are clear of personnel, then place the circuit breaker control in the **on** position.

> **NOTE:** Perform Step 5 only if the generator set is not being paralleled with an existing power source. If it is being paralleled with a power source already on the line, read and follow the instructions under *Paralleling* before turning the circuit breaker control to the **on** position.

PARALLELING

If the load conditions require an additional unit to be placed on the line, the following instructions will apply to power generator sets of equal capacity, with one generator set in operation on the line.

1. Prepare the generator set to be paralleled as outlined under *Preparation For Starting, Starting, Running* and Items 1 through 4 under *Preparing Generator for Load.*

2. Check the voltmeter (Fig. 1); the voltage must be the same as the line voltage. Adjust the voltage regulator rheostat control if the voltages are not the same.

3. Place the synchronizing lamp switch, of the generator set to be paralleled, in the **on** position.

4. Turn the vernier throttle knob until both units are operating at approximately the same frequency as indicated by the slow change in the brilliancy of the synchronizing lamps.

5. When the synchronizing lamps glow and then go out at a very slow rate, time the dark interval. Then, in the middle of this interval, turn the circuit breaker control to the **on** position. This places the incoming generator set on the line, with no load. The proper share of the existing load must now be placed on this generator.

6. The division of the kilowatt load between the alternating current generators operating in parallel depends on the power supplied by the engines to the generators as controlled by the engine governors and is practically independent of the generator excitation. Divide the kilowatt load between the generators by turning the vernier throttle knob counterclockwise on the incoming generator and clockwise on the generator that has been carrying the load (to keep the frequency of the generators constant) until both ammeters read the same, indicating that each generator is carrying its proper percentage of the total K.W. load.

7. The division of the reactive KVA load depends on the generator excitation as controlled by the voltage regulator. Divide the reactive load between the generators by turning the voltage regulator rheostat control on the incoming generator (generally clockwise to raise the voltage) until the ammeters read the same on both generator sets and the sum of the readings is minimum.

> **NOTE:** The generator sets are equipped with a resistor and current transformer connected in series with the voltage coil of the regulator (cross-current compensation) which equalizes most but not all of the reactive KVA load between the generators.

8. When the load is 80 per cent power factor lagging (motor and a few lights only), turn the vernier throttle knob on the incoming generator until the ammeter on that unit reads approximately 40 per cent of the total current load.

9. Rotate the voltage regulator rheostat control on the incoming generator clockwise to raise the voltage until the ammeters read the same on both units.

> **NOTE:** If a load was not added during paralleling, the total of the two ammeter readings should be the same as the reading before paralleling. Readjust the voltage regulator rheostat on the incoming generator, if necessary.

10. To reset the load voltage, turn the voltage regulator rheostat controls slowly on each unit. It is necessary to turn the controls the same amount and in the same direction to keep the reactive current equally divided.

Power generator sets with different capacities can also be paralleled by dividing the load proportionately to their capacity.

STOPPING

The procedure for stopping a power generator set or taking it out of parallel is as follows:

1. Turn off all of the load on the generator when stopping a single engine unit.

2. Shift the load from the generator when taking it out of parallel operation by turning the vernier throttle knob until the ammeter reads approximately zero.

3. Place the circuit breaker control in the **off** position.

4. Turn the voltage regulator rheostat control in a counterclockwise direction to the limit of its travel.

5. Press the throttle button and turn the throttle control to **stop** to shut-down the engine.

> **NOTE:** When performing a tune-up on a generator set that will be operated in parallel with another unit, adjust the speed droop as specified in *Engine Tune-Up*.

LUBRICATION AND PREVENTIVE MAINTENANCE

To obtain the best performance and long life from a Detroit Diesel engine, the Operator must adhere to the following schedule and instructions on lubrication and preventive maintenance.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions.*

The time intervals given in the chart on the following page are actual operating hours or miles of an engine. If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and, therefore, will drain readily.

All authorized *Detroit Diesel Allison Service Outlets* are prepared to service engines with the viscosity and grade of lubricants recommended on the following pages.

LUBRICATION AND PREVENTIVE MAINTENANCE CHART	Time Interval								
Hours		8	50	100	200	300	500	1,000	2,000
Item Operation Miles	Daily	240	1,500	3,000	6,000	9,000	15,000	30,000	60,000
1. Engine Oil	X								
2. Oil Filter*									
3. Coolant and Filter	X						X	X	
4. Hoses							X		
5. Radiator								X	
6. Heat Exchanger Electrodes and Core							X	X	
7. Raw Water Pump	X								
8. Fuel Tank	X						X		
9. Fuel Strainer and Filter						X			
10. Air Cleaners		X					X		
11. Air Box Drains							X	X	
12. Ventilating System								X	
13. Blower Screen								X	
14. Starting Motor*									
15. Battery-Charging Alternator				X	X		X		X
16. Battery				X					
17. Tachometer Drive and Clutch Controls				X					
18. Throttle Controls					X				
19. Engine Tune-Up*									
20. Drive Belts		X			X				
21. Overspeed Governor							X		
22. Fan Hub Bearings*									
23. Shut-Down System						X			
24. Hydrostarter System*									
25. Air Compressor Air Strainer					X				
26. Turbocharger*									
27. Power Generator				X		X			
28. Power Take-Off		X	X				X		
29. Torqmatic Converter	X		X				X		
30. Marine Gear	X				X			X**	

*See items on following pages **Twin Disc Marine Gear

Item 1

Check the oil level daily before starting the engine. Add oil, if necessary, to bring it to the proper level on the dipstick.

Select the proper grade of oil in accordance with the instructions in the *Lubricating Oil Specifications*.

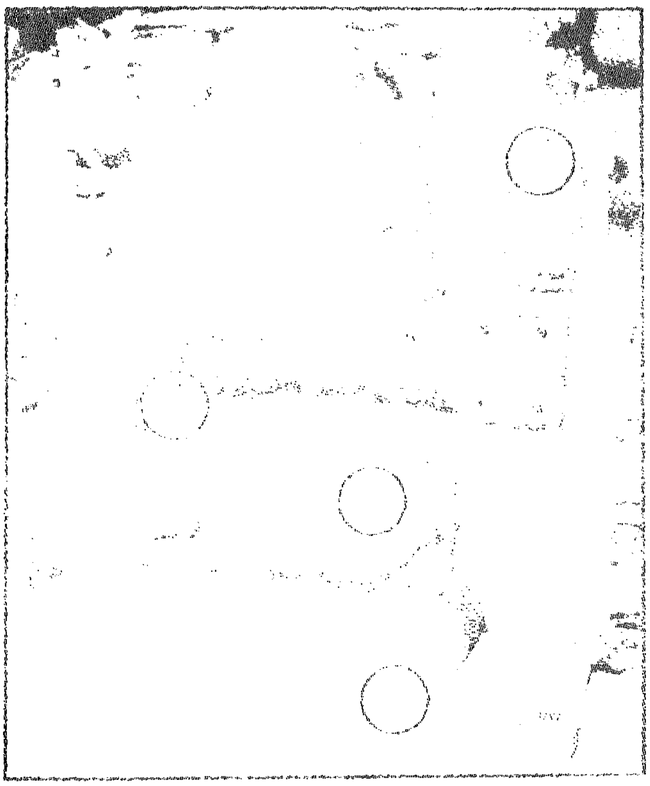
It is recommended that new engines be started with 100 hour oil change periods. The drain interval may then be gradually increased, or decreased, following the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the oil sample analysis) until the most practical oil change period has been established.

Item 2

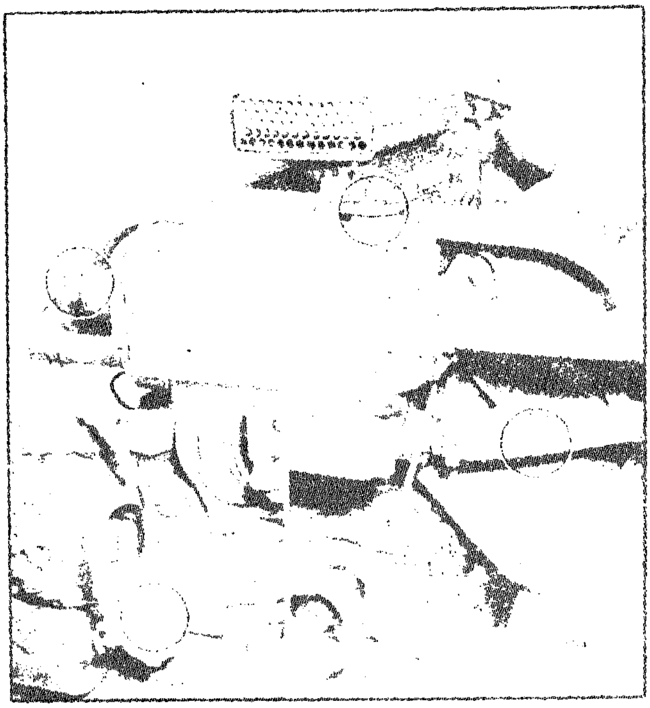
Install new engine oil filter elements and gaskets each time the engine oil is changed. Check for oil leaks after starting the engine. If the engine is equipped with a governor oil filter, change the element every 1,000 hours.

Item 3

Check the coolant level daily and maintain it near the



Items 1 and 2



Items 3 and 4

top of the heat exchanger tank or the radiator upper tank.

Clean the cooling system every 1,000 hours or 30,000 miles using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then fill the system with soft water, adding a good grade of rust inhibitor or a high boiling point type antifreeze (refer to *Engine Coolant*). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse-flushed.

If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 500 hours or 15,000 miles.

Item 4

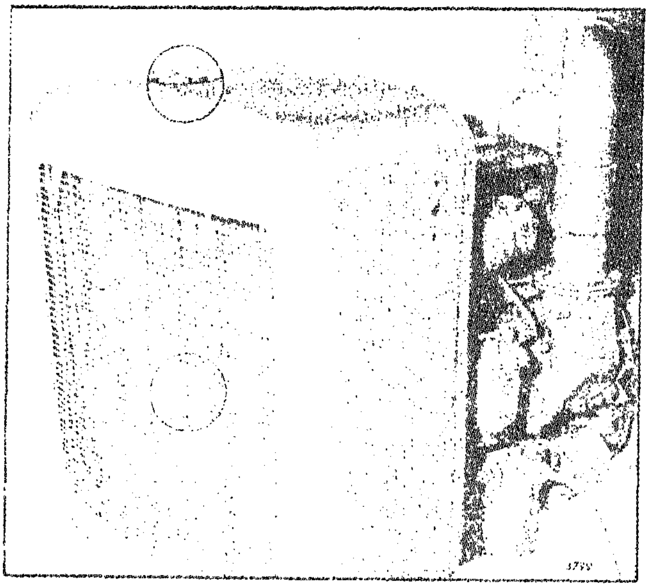
Inspect all of the cooling system hoses at least once every 500 hours or 15,000 miles for signs of deterioration. Replace the hoses if necessary.

Item 5

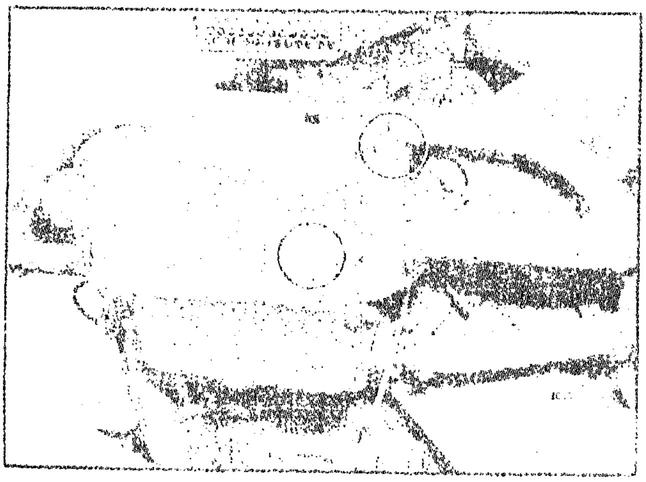
Inspect the exterior of the radiator core every 1,000 hours or 30,000 miles and, if necessary, clean it with a quality grease solvent such as Oleum and compressed air. *Do not use fuel oil, kerosene or gasoline.* It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Item 6

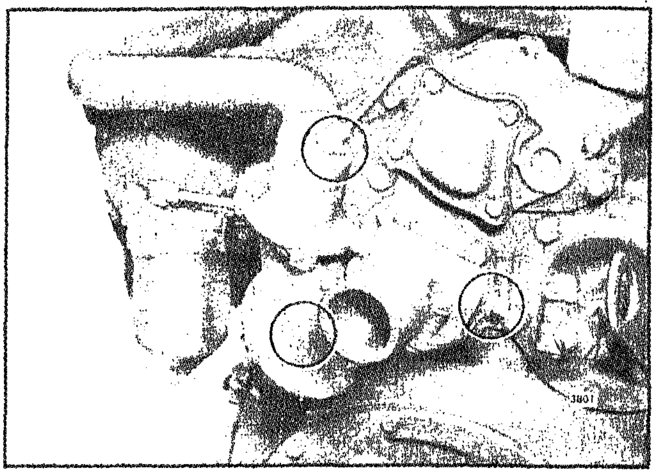
Every 500 hours drain the water from the heat exchanger raw water inlet and outlet tubes. Then remove the zinc electrodes from the inlet side of the



Item 5



Item 6



Item 7

raw water pump and the heat exchanger. Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Drain the cooling system, disconnect the raw water pipes at the outlet side of the heat exchanger and remove the retaining cover every 1,000 hours and inspect the heat exchanger core. If a considerable amount of scale or deposits are present, contact an authorized *Detroit Diesel Allison Service Outlet.*

Item 7

Check the prime on the raw water pump; the engine should not be operated with a dry pump. Prime the pump, if necessary, by removing the pipe plug provided in the pump inlet elbow and adding water. Reinstall the plug.

Item 8

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Diesel Fuel Oil Specifications.*

Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water or sediment.

Item 9

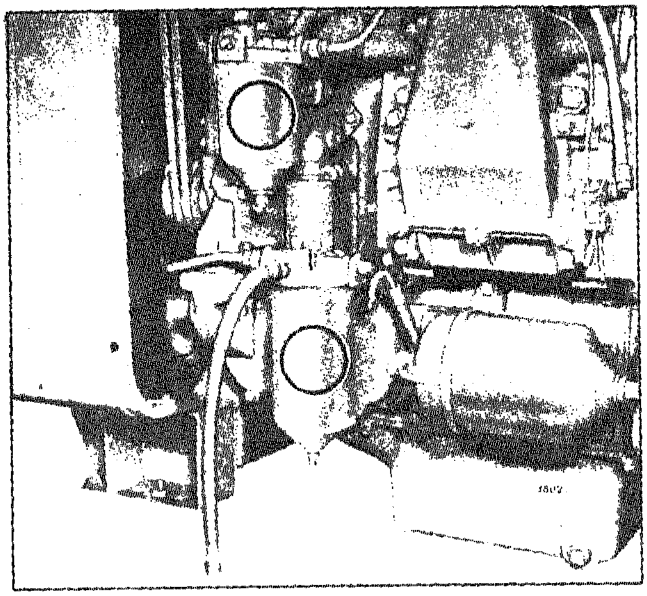
Install new elements every 300 hours or 9,000 miles or when plugging is indicated.

A method of determining when elements are plugged

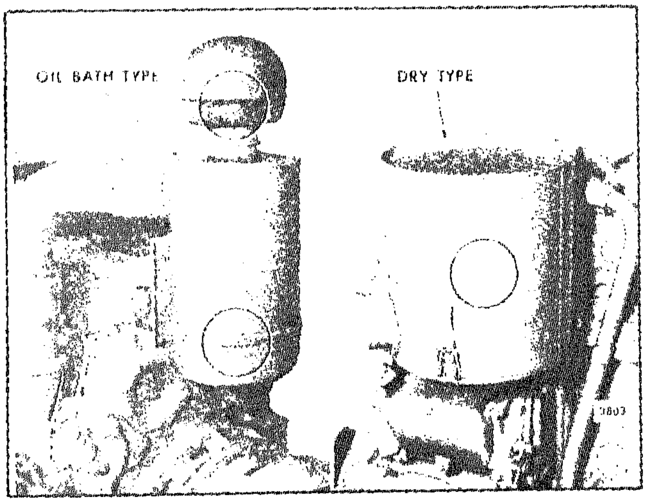
to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury. At normal operating speeds (1800-2800 rpm), the fuel pressure is 45 to 70 psi (310 to 483 kPa). Change the fuel filter elements whenever the inlet restriction (suction) at the fuel pump reaches 12 inches of mercury at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to 45 psi (310 kPa).

Item 10

Remove the dirty oil and sludge from the oil bath-type



Item 9



Item 10

air cleaner cups and center tubes every 8 hours or less if operating conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade of *heavy duty oil* as used in the engine. The frequency of servicing may be varied to suit local dust conditions.

It is recommended that the body and fixed element in the heavy-duty oil bath type air cleaner be serviced every 500 hours, 15,000 miles or as conditions warrant.

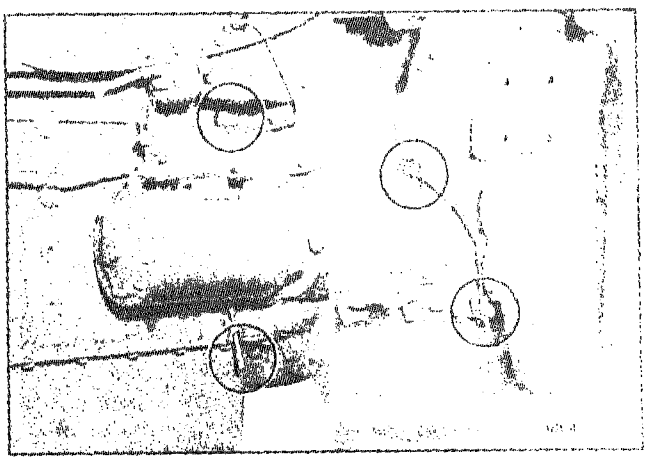
Clean or replace the element in the dry-type air cleaner when the restriction indicator instrument indicates high restriction or when a water manometer reading at the air inlet housing indicates the maximum allowable air inlet restriction (refer to the *Air Inlet Restriction* chart in the *Trouble Shooting* section). Refer to the instructions in the *Air System* section for servicing the dry-type air cleaner.

Item 11

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours or 30,000 miles. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent. If the engine is equipped with an air box drain tank, drain the sediment periodically. If the engine is equipped with an air box drain check valve, replace the valve every 500 hours or 15,000 miles.

Item 12

Clean the externally mounted crankcase breather assemblies every 1,000 hours or 30,000 miles. This cleaning period may be reduced or lengthened according to severity of service. Clean the internally



Item 11

mounted breather pads at time of engine overhaul, or sooner if excessive crankcase pressure is observed.

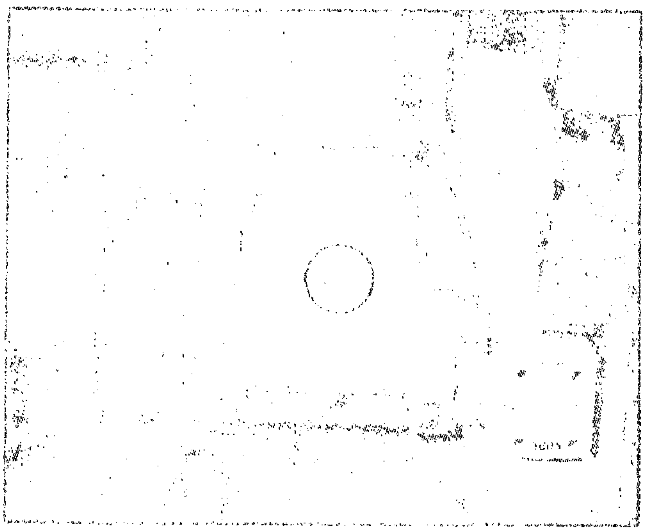
Remove the crankcase breather from the engine and wash the steel mesh pad (element) in fuel oil and dry it with compressed air. Reinstall the breather assembly.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.

Item 13

Inspect the blower screen and gasket assemblies every 1,000 hours or 30,000 miles and, if necessary, clean the screens in fuel oil and dry them with compressed air.

Item 12



Item 13

Reinstall the screen and gasket assemblies with the screen side of the assemblies toward the blower. Inspect for evidence of blower seal leakage.

Item 14

The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

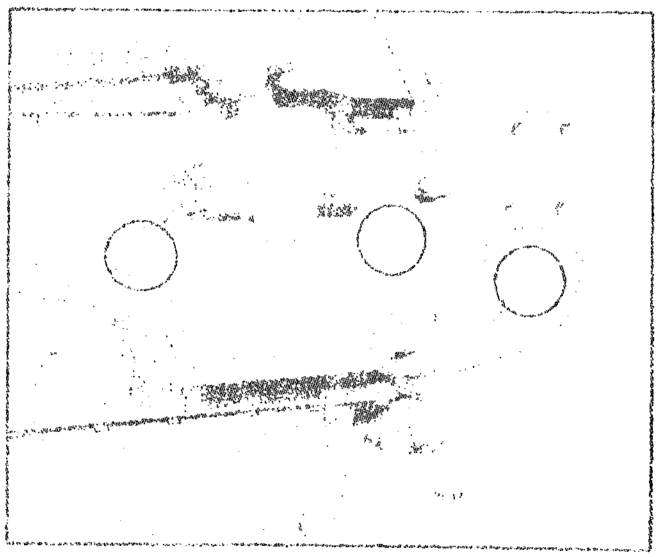
The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

Item 15

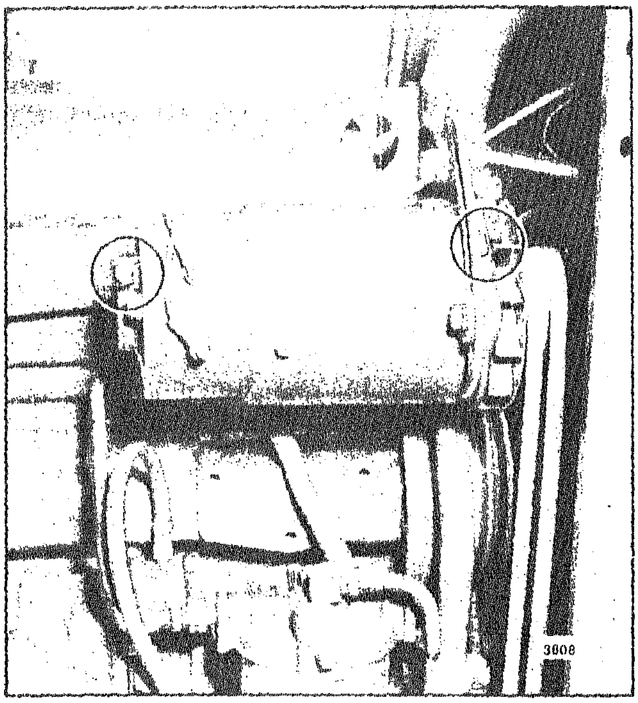
Lubricate the alternator bearings or bushings with 5 or 6 drops of engine oil at the hinge cap oiler every 200 hours or 6,000 miles.

Some alternators have a built-in supply of grease, while others use sealed bearings. In these latter two cases, additional lubrication is not necessary.

The slip rings and brushes of an alternator can be inspected through the end frame assembly. If the slip rings are dirty, they should be cleaned with 400 grain or finer polishing cloth. Never use emery cloth to clean slip rings. Hold the polishing cloth against the slip rings with the alternator in operation and blow away



Item 14



Item 15

all dust after the cleaning operation. If the slip rings are rough or out of round, replace them.

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

Item 16

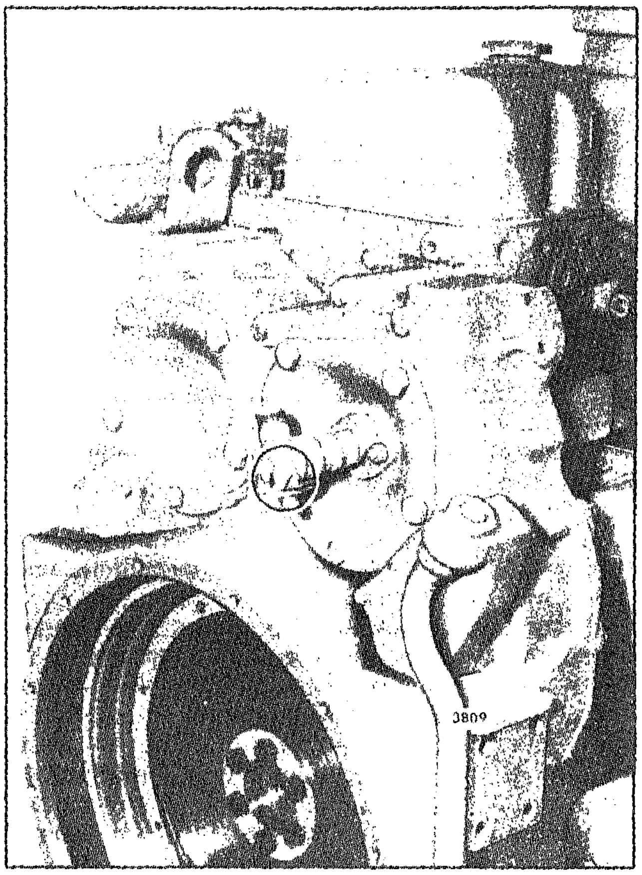
Check the specific gravity of the electrolyte in each cell of the battery every 100 hours or 3,000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 17

Lubricate the tachometer drive every 100 hours or 3,000 miles with an all purpose grease at the grease fitting. At temperatures above +30 °F (–1 °C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.

Item 18

Lubricate the throttle control mechanism every 200 hours or 6,000 miles with an all purpose grease. At



Item 17

temperatures above +30 °F (–1 °C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature. Lubricate all other control mechanisms, as required, with engine oil.

Item 19

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc. should only be required periodically to compensate for normal wear on parts.

Item 20

New drive belts will stretch after the first few hours of operation. Run the engine for 15 *seconds* to seat the belts and readjust the tension. Then check the belts and retighten the fan drive, pump drive and battery-charging alternator drive belts after 1/2 hour or 15 miles and again after 8 hours or 140 miles of operation. Thereafter, check the tension of the drive

belts every 200 hours or 6,000 miles and adjust, if necessary. Too tight a belt is destructive to the bearings of the driven part; a loose belt will slip.

BELT TENSION CHART (lbs/belt)

Model	Fan Drive		Generator Drive		
	2 or 3 belts	Single belt	Two 3/8" or 1/2" belts	One 1/2" belt	One 9/16" belt
3,4-53	40-50	-	40-50	50-70	40-50
6V-53	60-80	80-100	40-50	50-70	40-50
All	For 3-point or triangular drive use a tension of 90-120.				

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set: premature belt wear can result because of belt length variation. All belts in a matched set are within .032" of their specified center distances.

NOTE: When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2" to 3/4". If a belt tension gage such as BT-33-73FA or equivalent is available, adjust the belt tension as outlined in the chart.

Item 21

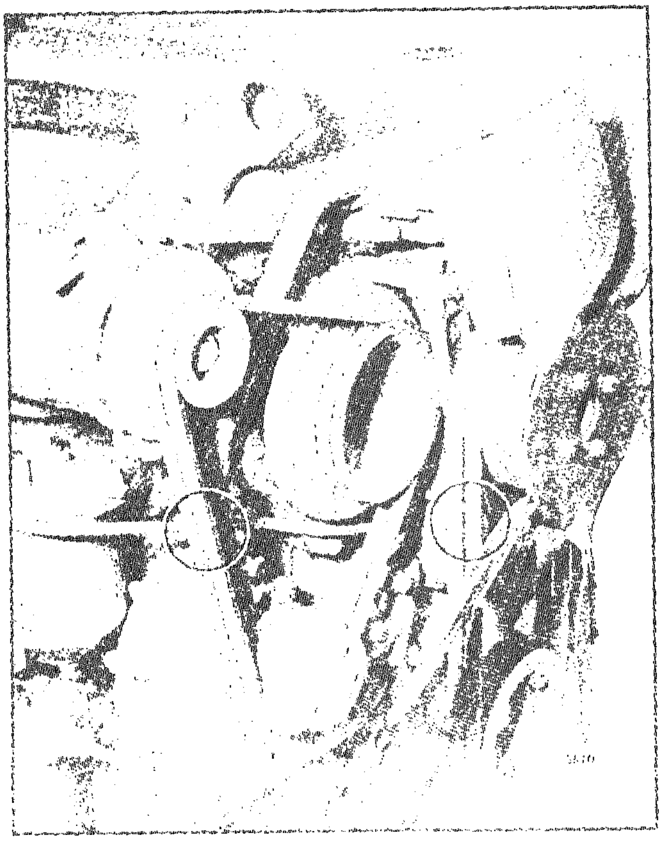
Lubricate the overspeed governor, if it is equipped with a hinge-type cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours. Avoid excessive lubrication and do not lubricate the governor while the engine is running.

Item 22

f the fan bearing hub assembly is provided with a rease fitting, use a hand grease gun and lubricate the earings with one shot of Texaco Premium RB grease, r an equivalent Lithium base multi-purpose grease, very 20,000 miles (approximately 700 hours).

very 75,000 miles or 2500 hours, clean, inspect and pack the fan bearing hub assembly with the above commended grease.

a major engine overhaul, remove and discard the arings in the fan hub assembly. Pack the hub sembly, using new bearings, with Texaco emium RB grease or an equivalent Lithium base ılti-purpose grease.



Item 20

Item 23

Check the shut-down system every 300 operating hours or each month to be sure it will function when needed.

Item 24

On engines equipped with a Hydrostarter, refer to the *Hydraulic Starting System* in the section on *Engine Equipment* for preventive maintenance and lubrication.

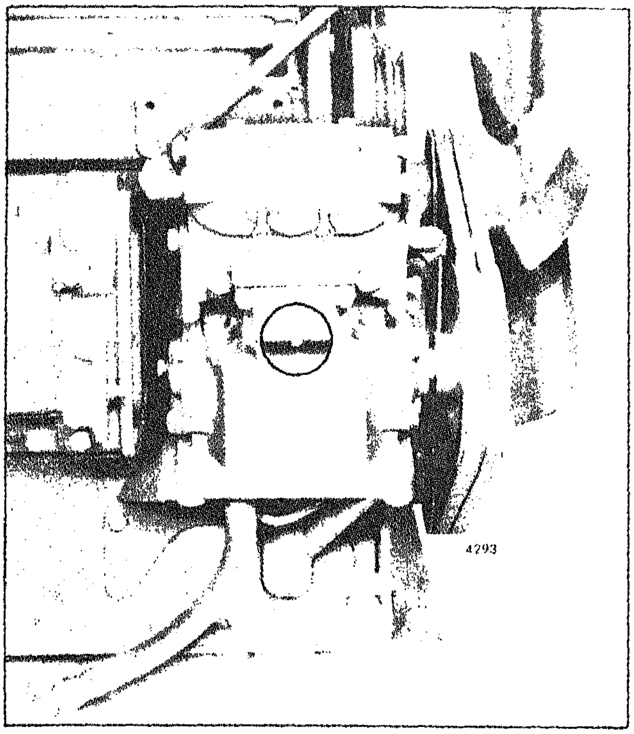
Item 25

To clean either the hair or polyurethane type air compressor air strainer element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until dirt free. Then dip it in lubricating oil and squeeze it dry before placing it back in the air strainer.

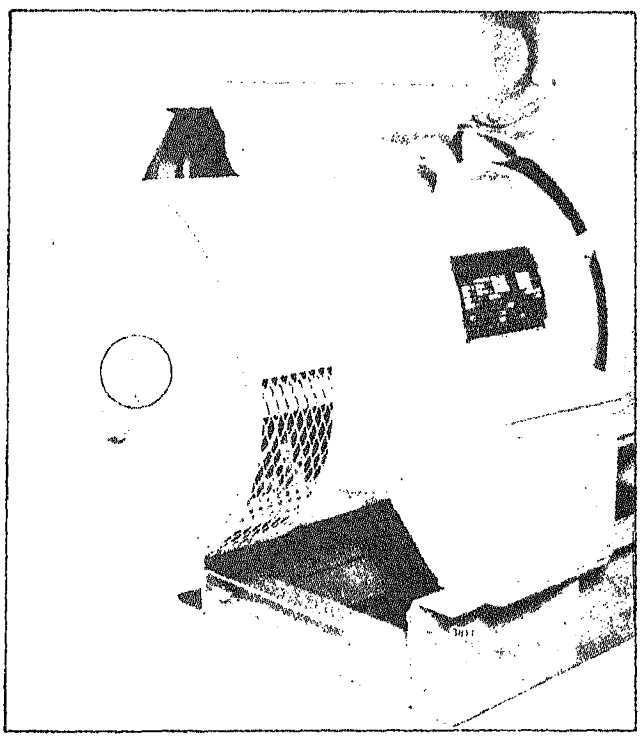
For replacement of the air strainer element, contact the nearest Bendix Westinghouse dealer; replace with the polyurethane element, if available.

Item 26

There is no scheduled interval for performing an inspection on the Airesearch turbocharger. As long as the turbocharger is operating satisfactorily and there



Item 25



Item 27

is no appreciable loss of power, no vibration or unusual noise and no oil leaks, only a periodic inspection is necessary. When service is required, contact an authorized *Detroit Diesel Allison Service Outlet.*

Item 27

The power generator requires lubrication at only one point - the ball bearing in the end frame.

If the bearing is oil lubricated, check the oil level in the sight gage every 300 hours; change the oil every six months. Use the same grade of oil as specified for the engine. Maintain the oil level to the line in the sight gage. **Do not overfill.** After adding oil, recheck the oil level after running the generator for several minutes.

If the bearing is grease lubricated, a new generator has sufficient grease for three years of normal service. Thereafter, it should be lubricated at one year intervals. To lubricate the bearing, remove the filler and relief plugs on the side and the bottom of the bearing reservoir. Add grease until new grease appears at the relief plug opening. Run the generator a few minutes to vent the excess grease; then reinstall the plugs.

The following greases, or their equivalents, are recommended:

Keystone 44H ....Keystone Lubrication Co.

BRB Lifetime ....Socony Vacuum Oil Co.

NY and NJ F926 or F927 ....NY and NJ Lubricant Co.

After 100 hours on new brushes, or brushes in generators that have not been in use over a long period, remove the end frame covers and inspect the brushes, commutator and collector rings. If there is no appreciable wear on the brushes, the inspection interval may be extended until the most practicable period has been established (not to exceed six months). To prevent damage to the commutator or the collector rings, do not permit the brushes to become shorter than 3/4 inch.

Keep the generator clean inside and out. Before removing the end frame covers, wipe off the loose dirt. The loose dirt and dust may be blown out with low pressure air (25 psi or 172 kPa maximum). Remove all greasy dirt with a cloth.

Item 28

Lubricate all of the power take-off bearings with an all purpose grease such as Shell Alvania No. 2, or

equivalent. Lubricate sparingly to avoid getting grease on the clutch facing.

Open the cover on the side of the clutch housing (8″ and 10″ diameter clutch) and lubricate the clutch release sleeve collar through the grease fitting every 8 hours. On the 11-1/2″ diameter clutch, lubricate the collar through the fitting on the side of the clutch housing every 8 hours.

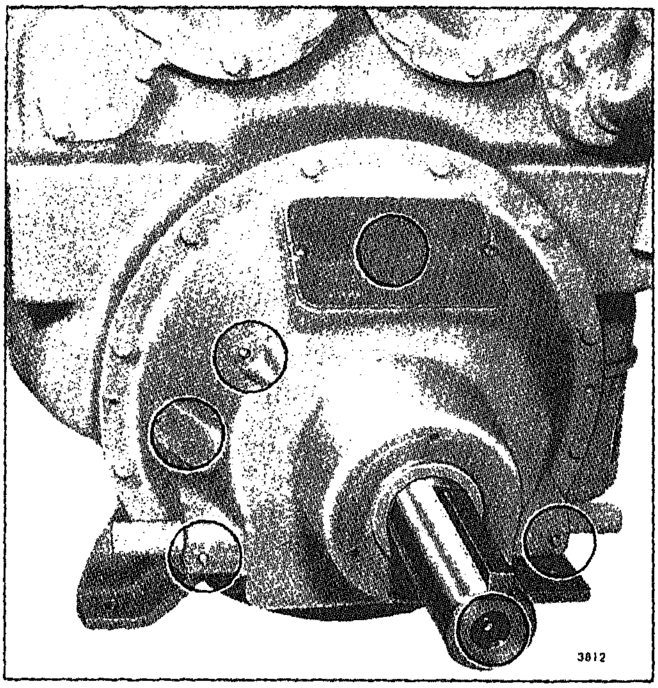
Lubricate the clutch drive shaft pilot bearing through the fitting in the outer end of the drive shaft (8″ and 10″ diameter clutch power take-offs) every 50 hours of operation. One or two strokes with a grease gun should be sufficient. The clutch drive shaft pilot bearing used with the 11-1/2″ diameter clutch power take-off is prelubricated and does not require lubrication.

Lubricate the clutch drive shaft roller bearings through the grease fitting in the clutch housing every 50 hours under normal operating conditions (not continuous) and more often under severe operating conditions or continuous operation.

Lubricate the clutch release shaft through the fittings at the rear of the housing every 500 hours of operation.

Lubricate the clutch levers and links sparingly with engine oil every 500 hours of operation. Remove the inspection hole cover on the clutch housing and lubricate the clutch release levers and pins with a hand oiler. To avoid getting oil on the clutch facing, do not over lubricate the clutch release levers and pins.

Check the clutch facing for wear every 500 hours. Adjust the clutch if necessary.



Item 28

Item 29

Check the oil level in the Torqmatic converter and supply tank daily. The oil level must be checked while the converter is operating, the engine idling and the oil is up to operating temperature (approximately 200° F). If the converter is equipped with an input disconnect clutch, the clutch must be engaged.

Check the oil level after running the unit a few minutes. The oil level should be maintained at the proper level on the dipstick. If required, add hydraulic transmission fluid type "C-2" (Table 1). *Do not overfill* the converter as too much oil will cause foaming and high oil temperature.

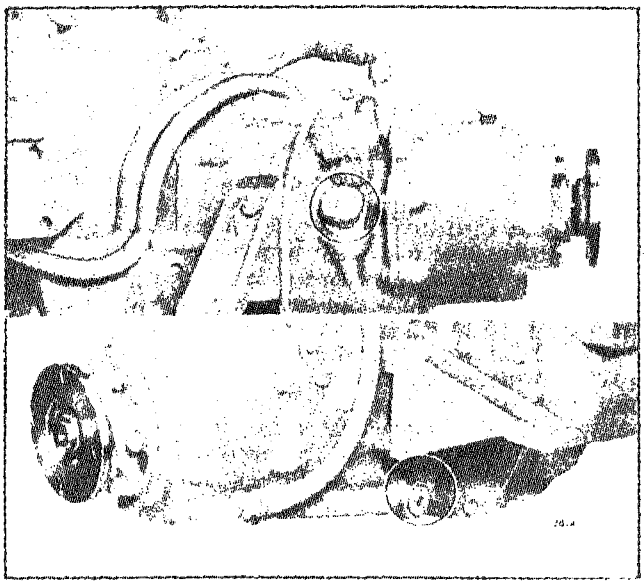
The oil should be changed every 500 hours of operation. Also, the oil should be changed whenever it shows traces of dirt or effects of high operating temperature as evidenced by discoloration or strong odor. If the oil shows metal contamination, contact an authorized *Detroit Diesel Allison Service Outlet* as this usually requires disassembly. Under severe operating conditions, the oil should be changed more often.

The converter oil breather, located on the oil level indicator (dipstick), should be cleaned each time the converter oil is changed. This can be accomplished by allowing the breather to soak in a solvent, then drying it with compressed air.

OIL RECOMMENDATIONS

Prevailing Ambient Temperature	Recommended Oil Specification
Above −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2.
Below −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2. Auxiliary preheat required to raise temperature in the sump to a temperature above −10°F. (−23° C)

TABLE 1



Item 30

The full-flow oil filter element should be removed, the shell cleaned and a new element and gasket installed each time the converter oil is changed.

Lubricate the input clutch release bearing and ball bearing every 50 hours with an all purpose grease through the grease fittings provided on the clutch housing. This time interval may vary depending upon the operating conditions. Over-lubrication will cause grease to be thrown on the clutch facing, causing th clutch to slip.

Item 30

WARNER MARINE GEAR:

Check the oil level daily. Start and run the engine a idle speed for a few minutes to fill the lubricatio system. Stop the engine. Then immediately afte stopping the engine, check the oil level in the marin gear. Bring the oil level up to the proper level on th dipstick. Use the same grade of lubricating oil that i used in the engine. **Do not overfill.**

Change the oil every 200 hours. After draining the oi from the unit, clean the removable oil screer thoroughly before refilling the marine gear with oil.

TWIN DISC MARINE GEAR:

Check the marine gear oil level daily. Check the oi level with the engine running at low idle speed and th gear in neutral. Keep the oil up to the proper level o the dipstick. Use oil of the same *heavy-duty* grade an viscosity that is used in the engine.

Change the oil every 200 hours. Remove and clean th oil inlet strainer screen after draining the oil an before refilling the marine gear. The strainer is locate in the sump at the lower end of the pump suction line When refilling after an oil drain, bring the oil up t the proper level on the dipstick (approximately quarts or 4.74 litres).

FUEL OIL SPECIFICATIONS

GENERAL CONSIDERATIONS

The quality of fuel oil used for high-speed diesel engine operation is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust.

Fuel selected should be completely distilled material. Fuels marketed to meet Federal Specification VV-F-800 (grades DF-1 and DF-2) and ASTM Designation D-975 (grades 1-D and 2-D) meet the completely distilled criteria. Some of the general properties of VV-F-800 and ASTM D-975 fuels are shown below.

FEDERAL SPECIFICATION & ASTM DIESEL FUEL PROPERTIES

Specification or Classification Grade	VV-F-800 DF-1	ASTM D-975 1-D	VV-F-800 DF-2	ASTM D-975 2-D
Flash Pt., °F min.	104 (40°C)	100 (38°C)	122 (50°C)	125 (52°C)
Carbon Residue (10% residuum), % max.	0.15	0.15	0.20	0.35
Water & Sediment, % by vol., max.	0.01	trace	0.01	0.05
Ash, % by wt., max.	0.005	0.01	0.005	0.01
Distillation Temperature, 90% by vol. recovery, min.	—	—	—	540°F (282°C)
max.	572°F (300°C)	550°F (288°C)	626°F (330°C)	640°F (338°C)
End Point, max.	626°F (330°C)	—	671°F (355°C)	—
Viscosity 100°F (38°C) Kinematic, cs, min.	1.4	1.4	2.0	2.0
Saybolt, SUS, min.	—	—	—	32.6
Kinematic, cs, max.	3.0	2.5	4.3	4.3
Saybolt, SUS, max.	—	34.4	—	40.1
Sulfur, % by wt., max.	0.50	0.50	0.50	0.50
Cetane No.	45	40	45	40

Residual fuels and domestic furnace oils are not considered satisfactory for Detroit Diesel engines; however, some may be acceptable. (See "DETROIT DIESEL FUEL OIL SPECIFICATIONS").

NOTE: Detroit Diesel Allison does not recommend the use of drained lubricating oil as a diesel fuel oil.

All diesel fuel oil contains a certain amount of sulfur. Too high a sulfur content results in excessive cylinder wear due to acid build-up in the lubricating oil. For most satisfactory engine life, fuels containing less than 0.5% sulfur should be used.

Fuel oil should be clean and free of contamination. Storage tanks should be inspected regularly for dirt, water or water-emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier.

SPECIFICATIONS

Detroit Diesel Allison designs, develops, and manufactures commercial diesel engines to operate on diesel fuels classified by the ASTM as Designation D-975 (grades 1-D and 2-D). These grades are very similar to grades DF-1 and DF-2 of Federal Specification VV-F-800. Residual fuels and furnace oils, generally, are not considered satisfactory for Detroit Diesel engines. In some regions, however, fuel suppliers may distribute one fuel that is marketed as either diesel fuel (ASTM D-975) or domestic heating fuel (ASTM D-396) sometimes identified as furnace oil. In this case, the fuel should be investigated to determine whether the properties conform with those shown in the "FUEL OIL SELECTION CHART" presented in this specification.

The "FUEL OIL SELECTION CHART" also will serve as a guide in the selection of the proper fuel for various applications. The fuels used must be clean, completely distilled, stable, and non-corrosive. DISTILLATION RANGE, CETANE NUMBER, and SULFUR CONTENT are three of the most important properties of diesel fuels that must be controlled to insure optimum combustion and minimum wear. Engine speed, load, and ambient temperature influence the selection of fuels with respect to distillation range and cetane number. The sulfur content of the fuel must be as low as possible to avoid excessive deposit formation, premature wear, and to minimize the sulfur dioxide exhausted into the atmosphere.

To assure that the fuel you use meets the required properties, enlist the aid of a reputable fuel oil supplier. The responsibility for clean fuel lies with the fuel supplier as well as the operator.

During cold weather engine operation, the cloud point (the temperature at which wax crystals begin to form in diesel fuel) should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

At temperatures below −20°F (−29°C), consult an authorized Detroit Diesel Allison service outlet, since particular attention must be given to the cooling system, lubricating system, fuel system, electrical system, and cold weather starting aids for efficient engine starting and operation.

FUEL OIL SELECTION CHART

Typical Application	General Fuel Classification	Final Boiling Point	Cetane No.	Sulfur Content
		(Max)	(Min)	(Max)
City Buses	No. 1-D	550°F (288°C)	45	0.30%
All Other Applications	Winter No. 2-D	675°F	45	0.50%
	Summer No. 2-D	675°F (357°C)	40	0.50%

NOTE: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of lighter distillate fuels may be more practical. The same consideration must be made when operating at altitudes above 5,000 ft.

LUBRICATING OIL SPECIFICATIONS

GENERAL CONSIDERATIONS

All diesel engines require heavy-duty lubricating oils. Basic requirements of such oils are lubricating quality, high heat resistance, control of contaminants.

LUBRICATING QUALITY. The reduction of friction and wear by maintaining an oil film between moving parts is the primary requisite of a lubricant. Film thickness and its ability to prevent metal-to-metal contact of moving parts is related to oil viscosity. The optimums for Detroit Diesel engines are SAE 30 or 40 weight.

HIGH HEAT RESISTANCE. Temperature is the most important factor in determining the rate at which deterioration or oxidation of the lubricating oil will occur. The oil should have adequate thermal stability at elevated temperatures, thereby precluding formation of harmful carbonaceous and/or ash deposits.

CONTROL OF CONTAMINANTS. The piston and compression rings must ride on a film of oil to minimize wear and prevent cylinder seizure. At normal rates of consumption, oil reaches a temperature zone at the upper part of the piston where rapid oxidation and carbonization can occur. In addition, as oil circulates through the engine, it is continuously contaminated by soot, acids, and water originating from combustion. Until they are exhausted, detergent and dispersant additives aid in keeping sludge and varnish from depositing on engine parts. But such additives in excessive quantities can result in detrimental ash deposits. If abnormal amounts of insoluble deposits form, particularly on the piston in the compression ring area, early engine failure may result.

Oil that is carried up the cylinder liner wall is normally consumed during engine operation. The oil and additives leave carbonaceous and/or ash deposits when subjected to the elevated temperatures of the combustion chamber. The amount of deposits is influenced by the oil composition, additive content, engine temperature, and oil consumption rate.

SPECIFICATIONS

OIL QUALITY

OIL QUALITY is the responsibility of the oil supplier. (The term *oil supplier* is applicable to refiners, blenders, and rebranders of petroleum products, and does not include distributors of such products.)

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The selection of a suitable lubricant in consultation with a reliable oil supplier, observance of his oil drain recommendations (based on used oil sample analysis and experience) and proper filter maintenance, will provide the best assurance of satisfactory oil performance.

Detroit Diesel Allison lubricant recommendations are based on general experience with current lubricants of various types and give consideration to the commercial lubricants presently available.

RECOMMENDATION

Detroit Diesel engines have given optimum performance and experienced the longest service life with the following oil performance levels having the ash and zinc limits shown:

Former Military and Commercial Lube Identification	New API Letter Code Service Classification	SAE Grade †
MIL-L-2104B/1964 MS Supplement 1	CC/SC CB	30 or 40 30 or 40

† SAE 40 grade oil has performed satisfactorily and is recommended in Detroit Diesel engines. Obviously, the expected ambient temperatures and engine cranking capability must be considered by the engine owner/operator when selecting the proper grade of oil. Only when the ambient temperatures and engine cranking capabilities result in difficult starting should SAE 30 grade oil be used.

<u>ASH LIMIT</u>
The sulfated ash limit (ASTM D-874) of the above lubricants shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.500% by weight is allowed. The majority of lubricants marketed under the performance levels shown above have a sulfated ash content between 0.55 to 0.85% by weight.

<u>ZINC CONTENT</u>
The zinc content, as zinc diorganodithiophosphate, shall be a minimum of 0.07% by weight.

RECOMMENDATIONS REGARDING THE USE OF CURRENT OIL PERFORMANCE LEVEL PRODUCTS MEETING PRESENT MILITARY LUBRICANT SPECIFICATIONS

The petroleum industry is currently marketing engine crankcase oils that may be identified as follows:

Military or Commercial Identification	API Letter Code Service Classification	Comment on Application and Performance
MIL-L-2104C	CD/SC	Supersedes MIL-L-45199B (Series 3) intended for diesel service.
MIL-L-46152	CC/SE	Supersedes MIL-L-2104B intended for gasoline engine passenger cars.
Universal	Numerous	Meets the performance criteria of all industry-accepted tests and all current military specifications including MIL-L-2104C and MIL-L-46152.

Detroit Diesel Allison does not have sufficient experience with any of the above described lubricants to recommend their use. Some oil suppliers have reported satisfactory performance of the above identified products marketed by them. If an owner/operator intends to use any of the above described products, it is recommended he obtain evidence from the oil supplier that the lubricant has performed satisfactorily in Detroit Diesel engines. The above products may be satisfactory for use in Detroit Diesel engines under the following conditions:

1. The sulfated ash (ASTM D-874) limit of the above lubricants shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.500% by weight is allowed.

2. The zinc content, as zinc diorganodithiophosphate, shall be a minimum of 0.07% by weight.

3. Sufficient evidence of satisfactory performance in Detroit Diesel engines has been provided to Detroit Diesel Allison and/or the customer.

LUBRICANTS NOT RECOMMENDED

The following lubricants are NOT recommended because of a history of poor performance in Detroit Diesel engines:

Military or Commercial Identification	API Letter Code Service Classification	Comment on Performance
MIL-L-2104B/1968 MS	CC/SD	Excessive ash deposits formed
MIL-L-45199B (Series 3)	CD	Excessive ash deposits formed
Multigrade oils	Numerous	History of poor performance in most heavy-duty diesel engines

COLD WEATHER OPERATION

Cold weather starting will be facilitated when immersion type electrical coolant heaters can be used. Other practical considerations, such as the use of batteries, cables and connectors of adequate size, generators or alternators of ample capacity, proper setting of voltage regulators, ether starting aids, oil and coolant heater systems, and proper fuel selection will accomplish starting with the use of SAE 30 or SAE 40 oils. For complete cold weather starting information, consult an authorized Detroit Diesel Allison service outlet. Ask for Engineering Bulletin No. 38 entitled, *Cold Weather Operation of Detroit Diesel Engines.*

MIL-L-46167 ARCTIC LUBE OILS FOR NORTH SLOPE & OTHER EXTREME SUB-ZERO OPERATIONS

The MIL-L-46167 specification was published by the Military on 15 February, 1974. Federal Test Method 354 of Federal Test Standard 791 is an integral test requirement of MIL-L-46167. *Lubricants that have passed the oil performance requirement limits of Method 354 may be used where continuous sub-zero temperatures prevail and where engines are shut down for periods longer than eight (8) hours.* The lubricants that have shown the best performance when subjected to Method 354 evaluation may be described as multigrades having a synthetic base stock and low volatility characteristics. These lubricants are not comparable to the performance of SAE 30 or 40 oils after the engine has started and is operating at elevated engine temperature conditions. For this reason, MIL-L-46167 lubricants should be considered only as a last resort when engine cranking is a severe problem and auxiliary heating aids are not available.

OIL CHANGES

The oil change period is dependent on the operating conditions (e.g. load factor, etc.) of an engine that will vary with the numerous service applications. It is recommended that new engines be started with 150 hour oil change periods. For highway vehicles this corresponds to approximately 4,500 miles, and for "city" service vehicles, approximately 2,500 miles. The drain interval may then be gradually increased or decreased with experience on a specific lubricant while also considering the recommendations of the oil supplier (analysis of the drained oil can be helpful here) until the most practical oil drain period for the particular service has been established.

Solvents should not be used as flushing oils in running engines. Dilution of the fresh refill oil supply can occur, which may be detrimental.

Full flow oil filtration systems have been used in Detroit Diesel engines since they have been manufactured. For the best results, the oil filter element should be replaced each time the oil is changed.

NEW ENGINE OIL CLASSIFICATION SYSTEM

A relatively new engine oil classification system has been introduced to industry that describes the criteria required to meet each performance level. A simplified cross-reference of oil and current commercial and military specifications is shown below.

CROSS-REFERENCE OF LUBE OIL CLASSIFICATION SYSTEMS

API Code Letters	Comparable Military or Commercial Industry Spec.
CA	MIL-L-2104A
CB	Supplement 1
CC	MIL-L-2104B (see Note below)
CD	MIL-L-45199B (Series 3)
‡	MIL-L-46152 (supersedes MIL-L-2104B for Military only)
■	MIL-L-2104C (supersedes MIL-L-45199B for Military only)
SA	none
SB	none
SC	1964 MS oils – Auto passenger car
SD	1968 MS oils – Auto passenger car
SE	1972 MS oils – Auto passenger car

‡ Oil performance meets or exceeds that of CC and SE oils.
■ Oil performance meets or exceeds that of CD and SC oils.
NOTE: MIL-L-2104B lubricants are currently marketed and readily avilable for commercial use. MIL-L-2104B lubricants are obsolete for Military service applications only.

Consult the following publications for complete descriptions:

1. Society of Automotive Engineers (SAE) Technical Report J-183a.
2. Federal Test Method Standard 791a.

PUBLICATION AVAILABLE SHOWING COMMERCIAL "BRAND" NAME LUBRICANTS

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled, *EMA Lubricating Oils Data Book for Heavy-Duty Automotive and Industrial Engines.* The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION
111 EAST WACKER DRIVE
CHICAGO, ILLINOIS 60601

STATEMENT OF POLICY ON FUEL AND LUBRICANT ADDITIVES

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpts have been taken from a policy statement of General Motors Corporation:

"It has been and continues to be General Motors policy to build motor vehicles that will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets. It is accordingly contrary to the policy of General Motors to recommend the regular and continued use of supplementary additives in such fuels and lubricants.

"This policy should not be confused with the fact that certain supplementary additives may effectively and economically solve specific operating problems which occasionally arise in some vehicles. In such instances, supplementary additives may be developed on the basis of suitable tests to remedy such problems without otherwise causing harm to vehicles. These selected products are then given official GM part numbers and made available for use in appropriate service applications.

"While General Motors Corporation assumes responsibility for the additives selected by it to remedy specific operating problems, it cannot, of course, accept responsibility for the many other additives which are constantly being marketed."

Although the stated Corporation policy is self-explanatory, the following is emphasized: *Detroit Diesel Allison does not recommend or support the use of any supplementary fuel or lubricant additives.* These include all products marketed as fuel conditioners, smoke suppressants, masking agents, reodorants, tune-up compounds, top oils, break-in oils, graphitizers and friction-reducing compounds.

NOTE: The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's fuel or lubricating recommendations may not be within the coverage of the warranty.

SERVICE AND INSPECTION INTERVALS

Generally, operating conditions will vary for each engine application, even with comparable mileage or hours and, therefore, maintenance schedules can vary. A good rule of thumb for piston, ring, and liner inspections, however, would be at 45,000 miles or 1500 hours for the first such inspection and at 30,000 miles or 1000 hour intervals thereafter.

A suggested preventive maintenance practice is a regularly scheduled testing of fuel and lubricating oils by either the oil supplier or an independent testing laboratory. Since the oil supplier knows the physical properties of his products best and maintains laboratories to determine practical oil drain intervals, take advantage of this service and request him to check drained oil samples frequently and report the results to you.

ENGINE COOLANT

Engine coolant is considered as any solution which is circulated through the engine to provide the means for heat transfer from the different engine components. In general, water containing various materials in solution is used for this purpose.

The function of the coolant is basic to the design and to the successful operation of the engine. Therefore, coolant must be carefully selected and properly maintained.

COOLANT REQUIREMENTS

A suitable coolant solution must meet the following basic requirements:

1. Provide for adequate heat transfer.

2. Provide a corrosion resistant environment within the cooling system.

3. Prevent formation of scale or sludge deposits in the cooling system.

4. Be compatible with the cooling system hose and seal materials.

5. Provide adequate freeze protection during cold weather operation.

The first four requirements are satisfied by combining a suitable water with reliable inhibitors. When operating conditions dictate the need for freeze protection, a solution of suitable water and a permanent antifreeze containing adequate inhibitors will provide a satisfactory coolant.

WATER

Any water, whether of drinking quality or not, will produce a corrosive environment in the cooling system. Also, scale deposits may form on the internal surfaces of the cooling system due to the mineral content of the water. Therefore, water selected as a coolant must be properly treated with inhibitors to control corrosion and scale deposition.

To determine if a particular water is suitable for use as a coolant when properly inhibited, the following characteristics must be considered: the concentration of chlorides, sulfates, total hardness and dissolved solids. Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium present) causes deposits of scale. Total dissolved solids may cause scale deposits, sludge deposits, corrosion or a combination of these. Chlorides, sulfates, magnesium and calcium are among but not necessarily all the materials which make up dissolved solids. Water, within the limits specified in Tables 1 and 2 of Fig. 1, is satisfactory as an engine coolant when proper inhibitors are added.

CORROSION INHIBITORS

A corrosion inhibitor is a water soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the

TABLE 1

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

Refer to Table 2 for evaluation of water intended for use in a coolant solution.

TABLE 2

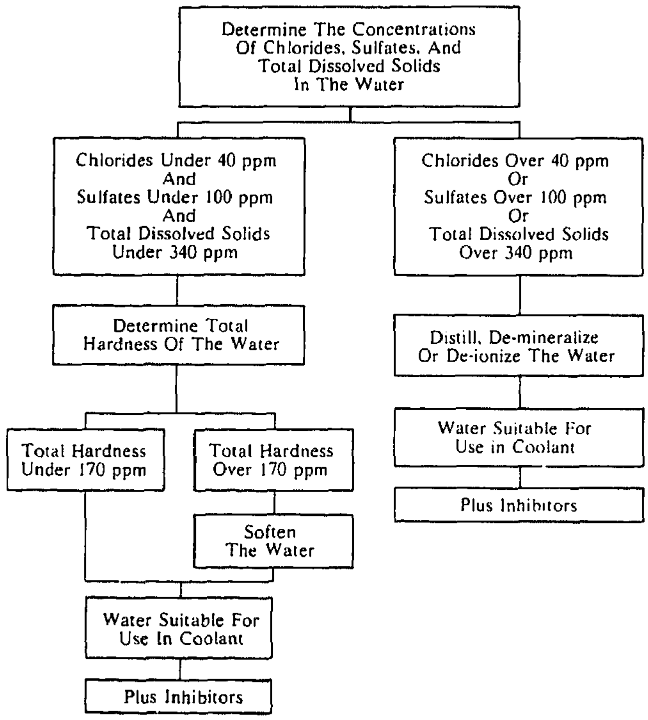


Fig. 1 - Water Characteristics

more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites and soluble oil. Depletion of all types of inhibitors occurs through normal operation. Therefore, strength levels must be maintained by the addition of inhibitors at prescribed intervals. Always follow the supplier's recommendations on inhibitor usage and handling.

Chromates

Sodium chromate and potassium dichromate are two of the best and most commonly used *water* system corrosion inhibitors. However, the restrictive use of these materials, due to ecology considerations, has de-emphasized their use in favor of non-chromates. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors should *not* be used in permanent type antifreeze solutions. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with permanent type antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate (Fig. 2) and results in engine overheating. Engines which have operated with a chromate-inhibited water must be chemically cleaned before the addition of permanent antifreeze. A commercial heavy-duty de-scaler should be used in accordance with the manufacturer's recommendation for this purpose.

Soluble Oil

Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if the concentration exceeds 1% by volume. For example: 1 1/4% of soluble oil in the cooling system increases fire deck temperature 6% and a 2 1/2% concentration raises fire deck temperature up to 15%. Soluble oil is *not* recommended as a corrosion inhibitor.

Non-chromates

Non-chromate inhibitors (borates, nitrates, nitrites, etc.) provide corrosion protection in the cooling system with the basic advantage that they can be used with either water or a water and permanent antifreeze solution.

INHIBITOR SYSTEMS

An inhibitor system (Fig. 3) is a combination of

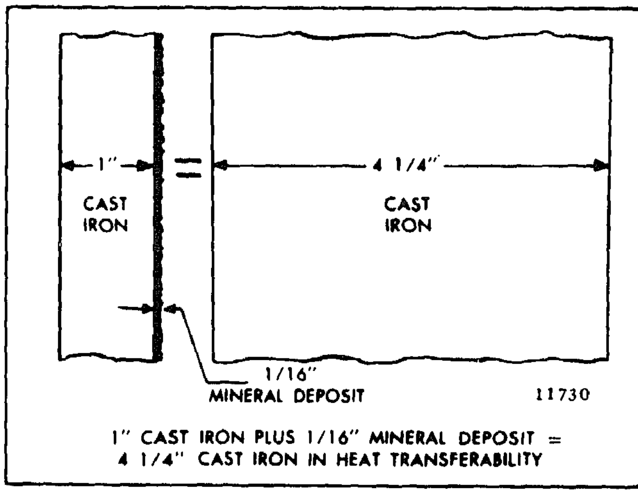


Fig. 2 - Heat Transfer Capacity

chemical compounds which provide corrosion protection, pH control and water softening ability. Corrosion protection is discussed under the heading *Corrosion Inhibitors*. The pH control is used to maintain an acid-free solution. The water softening ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant filter elements, liquid and dry bulk inhibitor additives, and as an integral part of permanent antifreeze.

Coolant Filter Elements

Replaceable elements are available with various chemical inhibitor systems. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

Problems have developed from the use of the magnesium lower support plate used by some manufacturers in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate in preference to magnesium is recommended to eliminate the potential of this type of deposit. High chloride coolants will have a detrimental effect on the water softening capabilities of systems using ion-exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by a regenerative process caused by high chloride content solutions.

Inhibitor or Inhibitor System	Corrosion Inhibitor Type	Inhibitor Compatability: Complete Inhibitor System	Water	Ethylene Glycol Base Antifreeze	*Methoxy Propanol Base Antifreeze
Sodium chromate	Chromate	No	Yes	No	No
Potassium dichromate	Chromate	No	Yes	No	No
Perry filter elements:					
5020 (type OS)	Chromate	Yes	Yes	No	No
S-453 (Spin-on)	Chromate	Yes	Yes	No	No
5030 (type OS)	@Non-chromate	Yes	Yes	Yes	No
S-331 (Spin-on)	@Non-chromate	Yes	Yes	Yes	No
5070 (type OS)	# Non-chromate	Yes	Yes	Yes	No
S-473 (Spin-on)	# Non-chromate	Yes	Yes	Yes	No
Lenroc filter element	Non-chromate	Yes	Yes	Yes	No
Fleetguard filter elements:					
DCA (canister)	Non-chromate	Yes	Yes	Yes	No
DCA (Spin-on)	Non-chromate	Yes	Yes	Yes	No
AC filter elements:					
DCA (canister)	Non-chromate	Yes	Yes	Yes	No
DCA (Spin-on)	Non-chromate	Yes	Yes	Yes	No
Luber-Finer filter elements:					
LW-4739 (canister)	Non-chromate	Yes	Yes	Yes	No
LFW-4744 (spin-on)	Non-chromate	Yes	Yes	Yes	No
Nalcool 2000 (liquid)	Non-chromate	Yes	Yes	Yes	No
Perry LP-20 (liquid)	Non-chromate	Yes	Yes	Yes	No
Lubercool (liquid)	Non-chromate	Yes	Yes	Yes	No
Dowtherm cooling system conditioner	Non-chromate	Yes	Yes	Yes	Yes

*Dowtherm 209, or equivalent.
@Perry "Year Around" formula.
Perry "Universal" formula.

Fig. 3 - Coolant Inhibitor Chart

Bulk Inhibitor Additives

Commercially packaged inhibitor systems are available which can be added directly to the engine coolant or to bulk storage tanks containing coolant solution. Both chromate and non-chromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

Non-chromate inhibitor systems are recommended for use in Detroit Diesel engines. These systems can be used with either water or permanent antifreeze solutions and provide corrosion protection, pH control and water softening. Some non-chromate inhibitor systems offer the additional advantage of a simple on-site test to determine protection level and, since they are added directly to the coolant, require no additional hardware or plumbing.

All inhibitors become depleted through normal

operation and additional inhibitor must be added to the coolant at prescribed intervals to maintain original strength levels. Always follow the supplier's recommendations on inhibitor usage and handling.

NOTE: Methoxy propanol base permanent antifreeze (such as Dowtherm 209, or equivalent) must be re-inhibited only with compatible corrosion inhibitor systems.

ANTIFREEZE

When freeze protection is required, a permanent antifreeze must be used. An inhibitor system is included in this type of antifreeze and no additional inhibitors are required on initial fill if a minimum antifreeze concentration of 30% by volume is used. Solutions of less than 30% concentration do not provide sufficient corrosion protection. Concentrations over 67% adversely affect freeze protection and heat transfer rates.

Ethylene glycol base antifreeze is recommended for use in Detroit Diesel engines. Methyl alcohol antifreeze is *not* recommended because of its effect on the non-metallic components of the cooling system and because of its low boiling point. Methoxy propanol base antifreeze may be used for freeze protection in Detroit Diesel Series 53 engines. Before installing methoxy propanol base antifreeze in a unit, the entire cooling system should be drained, flushed with clean water and examined for rust, scale, contaminants, etc. If deposits are present, the cooling system must be chemically cleaned with a commercial grade heavy-duty de-scaler.

The inhibitors in permanent antifreeze should be replenished at approximately 500 hour or 20,000 mile intervals with a non-chromate inhibitor sytem. Commercially available inhibitor systems may be used to re-inhibit antifreeze solutions.

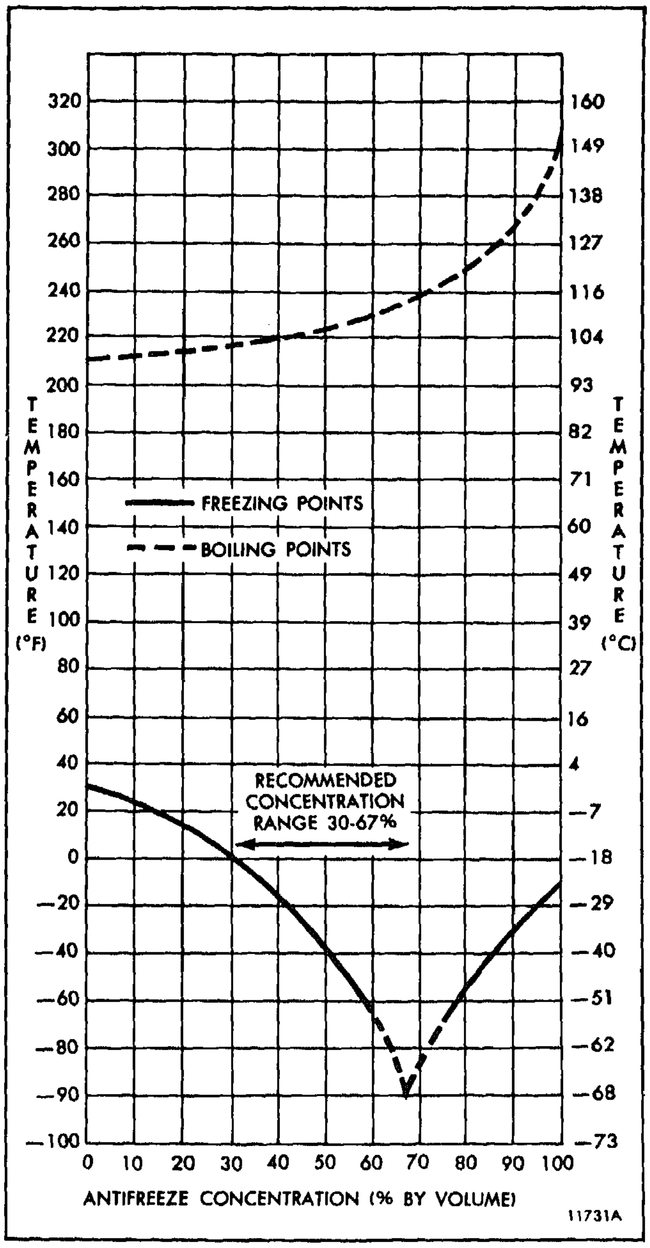


Fig. 4 - Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

Sealer Additives

Several brands of permanent antifreeze are available with sealer additives. The specific type of sealer varies with the manufacturer. Antifreeze with sealer additives is *not recommended* for use in Detroit Diesel engines due to possible plugging throughout various areas of the cooling system.

GENERAL RECOMMENDATIONS

All Detroit Diesel engines incorporate pressurized cooling systems which normally operate at temperatures higher than non-pressurized systems. It is essential that these systems be kept clean and leak-free, that filler caps and pressure relief mechanisms be correctly installed at all times and that coolant levels be properly maintained.

WARNING: Use extreme care when removing a radiator pressure control cap from an engine. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

1. Always use a properly inhibited coolant.

2. Do not use soluble oil.

3. Maintain the prescribed inhibitor strength.

4. Always follow the manufacturer's recommendations on inhibitor usage and handling.

5. If freeze protection is required, always use a permanent antifreeze.

6. Re-inhibit antifreeze with a recommended non-chromate inhibitor system.

7. Do not use a chromate inhibitor with permanent antifreeze.

8. DO NOT mix ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.

9. Do not use an antifreeze containing sealer additives.

10. Do not use methyl alcohol base antifreeze.

11. Use extreme care when removing the radiator pressure control cap.

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc. should only be required periodically to compensate for normal wear on parts.

Three types of governors are used. Since each governor has different characteristics, the tune-up procedure varies accordingly. The three types are:

1. Limiting speed mechanical.
2. Variable speed mechanical.
3. Hydraulic.

The mechanical engine governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor. A single-weight variable speed governor name plate is stamped S.W.-V.S.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if the cylinder head, governor or injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

To tune-up an engine completely, all of the adjustments are made by following the applicable tune-up sequence given below after the engine has reached the normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Tune-Up Sequence for Mechanical Governor

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the buffer screw.
8. Adjust the throttle booster spring (variable spd governor only).
9. Adjust the supplementary governing device f used).

Tune-Up Sequence for Hydraulic Governor

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the fuel rod.
4. Position the injector rack control levers.
5. Adjust the load limit screw.
6. Adjust the speed droop.
7. Adjust the maximum no-load speed.

NOTE: Use new valve rocker cover gasket(s) after each tune-up.

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders, and eventually burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, especially in the low speed range.

Whenever the cylinder head is overhauled, the exhaust valves reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting which is close enough to the specified clearance to prevent damage to the valves when the engine is started.

All of the exhaust valves may be adjusted, in firing order sequence, during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

TWO VALVE CYLINDER HEADS

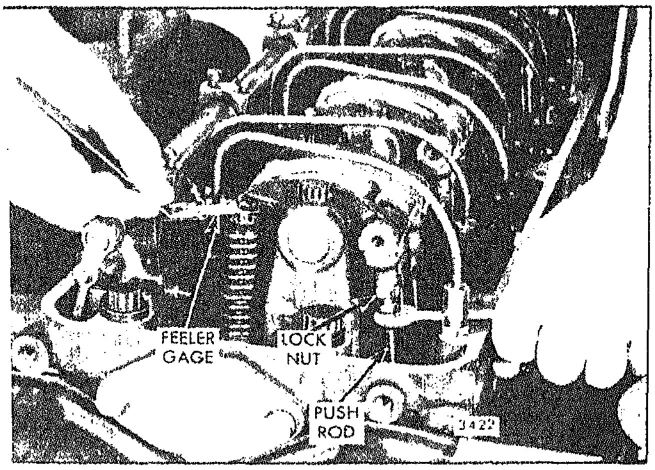


Fig. 1 - Adjusting Valve Clearance (Two-Valve Cylinder Head)

Cold Engine

1. Place the speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *no-fuel* position.

2. Remove the loose dirt from the valve rocker cover(s) and remove the cover(s).

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is fully depressed on the cylinder to be adjusted.

CAUTION: If a wrench is used on the crankshaft bolt, do not turn the engine in a left-hand direction of rotation as the bolt will be loosened.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a .012" feeler gage, J 9708, between the valve stem and the rocker arm (Fig. 1). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the lock nut with a 1/2" wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the .010" gage will pass freely between the end of the valve stem and the rocker arm and the .012" gage will not pass through.

8. Check and adjust the remaining valves in the same manner as outlined above.

Hot Engine

Maintaining normal engine operating temperature is particularly important when making the final valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance, when running at full load, may become insufficient.

1. With the engine at normal operating temperature (160-185 °F or 71-85 °C), recheck the exhaust valve clearance with feeler gage J 9708. At this time, if the valve clearance is correct, the .008" gage will pass freely between the end of the valve stem and the rocker arm and the .010" gage will not pass through. Readjust the push rod, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing.

FOUR VALVE CYLINDER HEADS

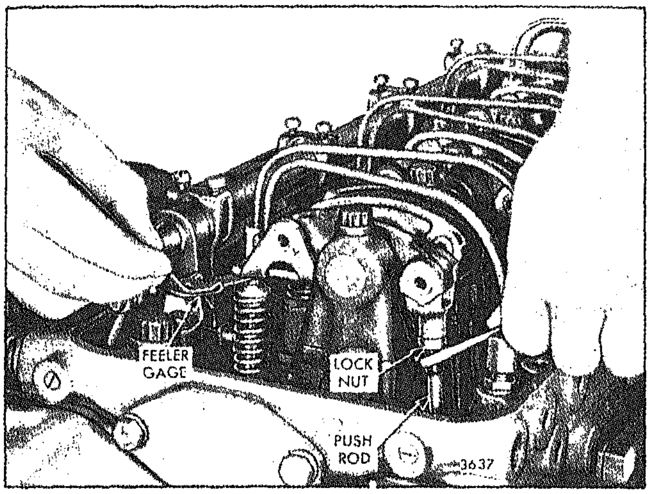


Fig. 2 - Adjusting Valve Clearance (Four-Valve Cylinder Head)

Cold Engine

1. Place the speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *no-fuel* position.

2. Remove the loose dirt from the valve rocker cover(s) and remove the cover(s).

3. Rotate the crankshaft until the injector follower is fully depressed on the cylinder to be adjusted.

> **CAUTION:** If a wrench is used on the crankshaft bolt, do not turn the engine in a left-hand direction of rotation as the bolt will be loosened.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a .027" feeler gage, J 9708, between the end of one valve stem and the rocker arm bridge (Fig. 2). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the lock nut with a 1/2" wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the .025" gage will pass freely between the end of one valve stem and the rocker arm bridge and the .027" gage will not pass through. Readjust the push rod if necessary.

8. Check and adjust the remaining exhaust valves, in the same manner as above.

Hot Engine

Maintaining normal engine operating temperature is particularly important when making the final valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance, when running at full load, may become insufficient.

1. With the engine at normal operating temperature (160-185°F or 71-85°C), recheck the exhaust valve clearance with gage J 9708. At this time, if the valve clearance is correct, the .023" gage should pass freely between the end of one valve stem and the rocker arm bridge and the .025" feeler gage should not. Readjust the push rod, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing.

TIMING FUEL INJECTOR

Injector	Timing Dimension	Tool Number
*35	1.508	J 8909
35	1.484	J 1242
40	1.484	J 1242
45	1.484	J 1242
S40	1.460	J 1853
S45	1.460	J 1853
S50	1.460	J 1853
L40	1.460	J 1853
N40	1.460	J 1853
N45	1.460	J 1853
N50	1.460	J 1853

***Reefer Car**

To time a fuel injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed, in firing order sequence, during one full revolution of the crankshaft.

Time Fuel Injector

After the exhaust valve clearance has been adjusted, time the fuel injector as follows:

1. Place the speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *no-fuel* position.

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

> **CAUTION:** If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt will be loosened.

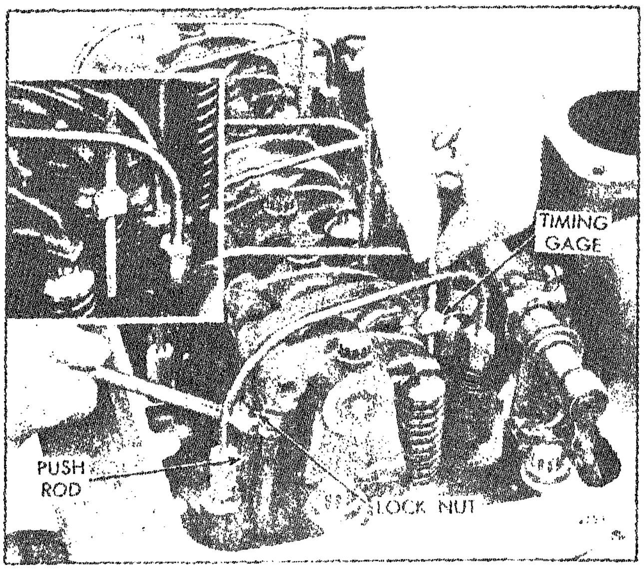


Fig. 3 · Timing Fuel Injector

3. Place the small end of the injector timing gage (see table for correct timing gage) in the hole provided in the top of the injector body, with the flat of the gage toward the injector follower as shown in Fig. 3.

4. Loosen the push rod lock nut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

6. Hold the push rod and tighten the lock nut. Check the adjustment and readjust, if necessary.

7. Time the remaining injectors as outlined above.

8. If no further engine tune-up is required, use a new gasket(s) and install the valve rocker cover(s).

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINES

The double-weight limiting speed governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

> **NOTE:** Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, re-connect and adjust the supplementary governing device.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Remove the high-speed spring retainer cover.

2. Back out the buffer screw (Fig. 8) until it extends approximately 5/8″ from the lock nut.

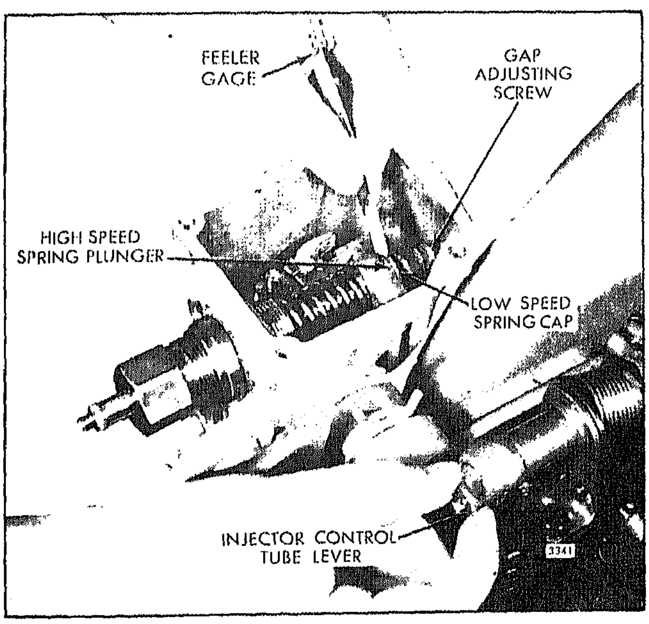


Fig. 1 - Adjusting Governor Gap

3. Start the engine and adjust the idle speed screw (Fig. 7) to obtain the desired engine idle speed. Hold the screw and tighten the lock nut to hold the adjustment.

> **NOTE:** The recommended idle speed for non-EPA certified engines is 500-600 rpm, but may vary with special engine applications.

4. Stop the engine, clean and remove the governor cover and the valve rocker cover. Discard the gaskets.

5. Start and run the engine, between 800 and 1000 rpm by manual operation of the injector control tube lever.

> **CAUTION:** Do not overspeed the engine.

6. Check the gap between the low-speed spring cap and the high-speed spring plunger with a .0015″ feeler gage. If the gap setting is incorrect, reset the gap adjusting screw (Fig. 1). If the setting is correct, the .0015″ movement can be seen by placing a few drops of oil into the governor gap and pressing a screw driver against the gap adjusting screw. Movement of

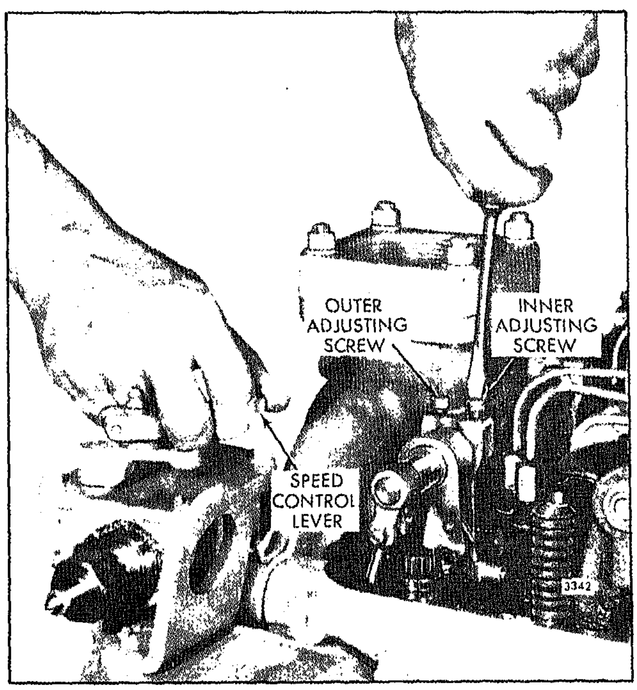


Fig. 2 - Positioning the Rear Injector Rack Control Lever

cap toward the plunger will force the oil from the
in the form of a small bead.

Hold the gap adjusting screw and tighten the lock
.

Recheck the gap and readjust if necessary.

Stop the engine and, using a new gasket, install the
vernor cover. The governor cover should be placed
the housing with the pin of the speed control lever
jecting into the slot of the differential lever.

Install the screws and lock washers finger tight. Pull
cover away from the engine and tighten the
ews. This step will properly locate the cover on the
vernor housing.

sition Injector Rack Control Levers

e position of the injector racks must be correctly set
relation to the governor. Their position determines
amount of fuel injected into each cylinder and
sures equal distribution of the load. Properly
sitioned injector rack control levers with the engine
full-load will result in the following:

Speed control lever at the full-fuel position.

Governor low-speed gap closed.

High-speed spring plunger on the seat in the
vernor control housing.

Injector racks in the full-fuel position.

just the rear injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

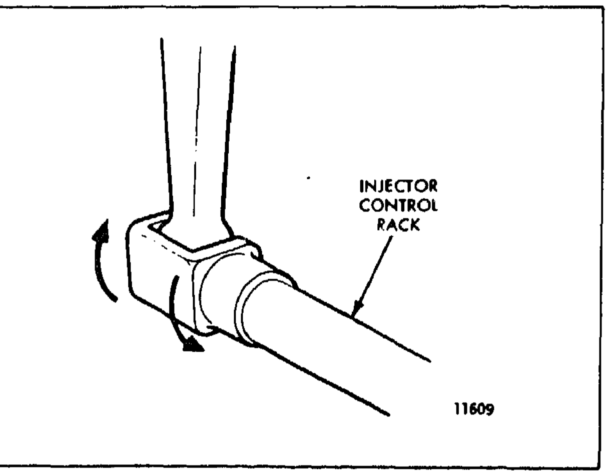


Fig. 3 - Checking Rotating Movement of Injector Control Rack

1. Disconnect any linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until 1/2" of the threads (12-14 threads) project from the lock nut, when the nut is against the high-speed plunger.

> **CAUTION:** A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

> **NOTE:** This adjustment lowers the tension of the low-speed spring so it can be easily compressed. This permits closing the low speed gap without bending the fuel rods or causing the *yield mechanism springs to yield or stretch.*

3. Back out the buffer screw approximately 5/8", if it has not already been done.

4. Loosen all of the inner and outer injector rack control lever adjusting screws (Fig. 2). Be sure all of the levers are free on the injector control tube.

5. Move the speed control lever to the maximum speed position. Turn the inner adjusting screw down on the rear injector rack control lever until a step-up in effort is noted. This will place the rear injector rack in the full-fuel position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws. This should result in placing the governor linkage and control tube assembly in the

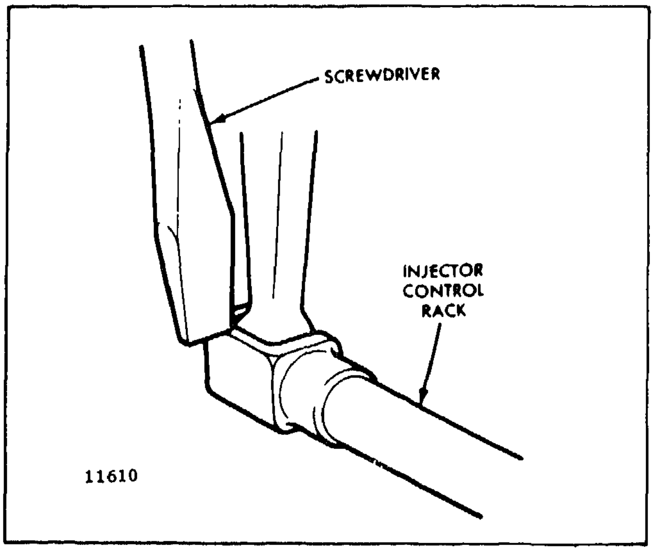


Fig. 4 - Checking Injector Rack "Spring"

same positions that they will attain while the engine is running at full-load.

6. To be sure of the proper rack adjustment, hold the speed control lever in the full-fuel position and press down on the injector rack with a screw driver or finger tip and note "rotating" movement of the injector control rack (Fig. 3) when the speed control lever is in the maximum speed position. Hold the speed control lever in the maximum speed position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Fig. 4) and when the pressure of the screw driver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly.

The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel. To correct this condition, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lbs** (3-4 Nm).

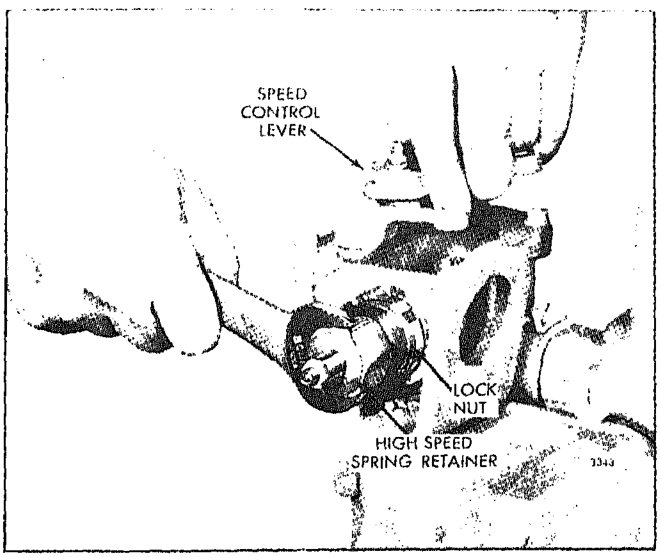


Fig. 5 - Adjusting Maximum No-Load Engine Speed (Type A)

> **IMPORTANT:** The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

7. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rod and the injector control tube lever, hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

8. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

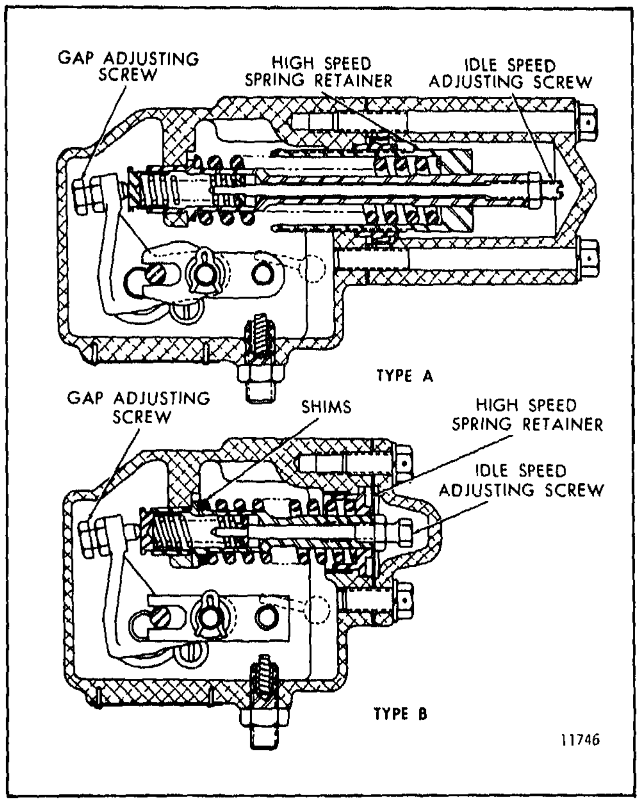


Fig. 6 - Governor Spring Assemblies

[redacted]

9. Position the remaining injector rack control levers as outlined in Steps 6 and 7.

10. Connect the fuel rod to the injector control tube lever.

11. Turn the idle speed adjusting screw in until it projects 3/16" from the lock nut to permit starting the engine. Tighten the lock nut.

12. Use a new gasket and replace the valve rocker cover.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, set the maximum no-load speed as follows:

TYPE A GOVERNOR SPRINGS (Fig. 6):

1. Loosen the lock nut (Fig. 5) and back off the high-speed spring retainer approximately five turns.

2. With the engine at operating temperature and no-load on the engine, place the speed control lever in the full-fuel position. Turn the high-speed spring retainer IN until the engine is operating at the recommended no-load speed.

The best method of determining the engine speed is with an accurate tachometer.

3. Hold the high-speed spring retainer and tighten the lock nut.

TYPE B GOVERNOR SPRINGS (Fig. 6):

1. Start the engine and after it reaches normal operating temperature, remove the load from the engine.

2. Place the speed control lever in the maximum speed position and note the engine speed.

3. Stop the engine and, if necessary, adjust the no-load speed as follows:

a. Remove the high-speed spring retainer, high-speed spring and plunger.

CAUTION: To prevent the low-speed spring and cap from dropping into the governor, be careful not to jar the assembly while it is being removed.

b. Remove the high-speed spring from the high-speed spring plunger and add or remove shims (Fig. 6) as required to establish the desired engine no-load speed.

NOTE: For each .010" shim added, the engine speed will be increased approximately 10 rpm.

c. Install the high-speed spring on the plunger and install the spring assembly in the governor housing. Install the spring retainer in the governor housing and tighten it securely.

d. Start the engine and recheck the engine no-load speed. Repeat the procedure as necessary to establish the no-load speed.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 7) until the engine is operating at approximately 15 rpm below the recommended idle speed.

NOTE: The recommended idle speed for non-EPA certified engines is 500-600 rpm, but may vary with special engine applications.

2. Hold the idle speed adjusting screw and tighten the lock nut.

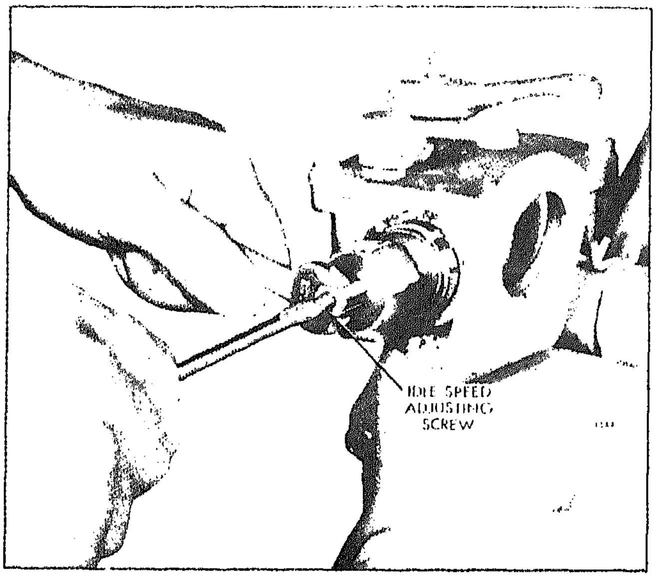


Fig. 7 - Adjusting Engine Idle Speed

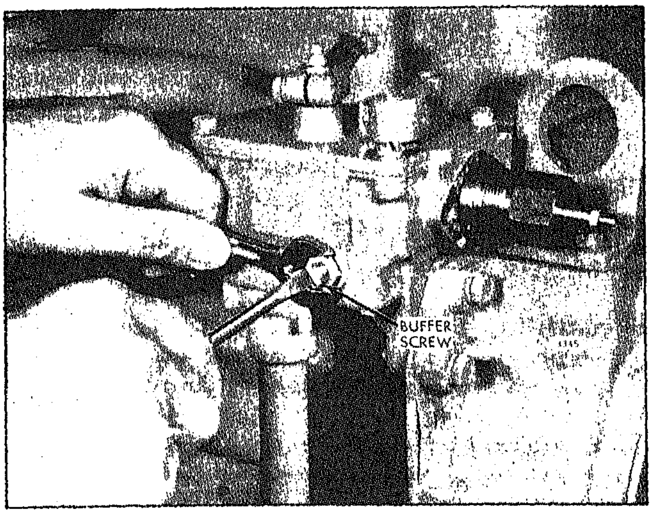


Fig. 8 - Adjusting Buffer Screw

3. Install the high-speed spring cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 8) so it contacts the differential lever as lightly as possible and still eliminates engine roll.

> **NOTE:** Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the lock nut.

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

6V-53 ENGINE

The limiting speed mechanical governor is mounted at the rear of the engine, between the flywheel housing and the blower (Fig. 1). The governor is driven by the right blower rotor drive gear. The left blower rotor drive gear is driven by a shaft, that passes through the governor housing, from the engine gear train. There are two types of limiting speed governor assemblies. The difference in the two governors is in the spring mechanism (Fig. 7). One has a long spring mechanism, the other has a short spring mechanism.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

NOTE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, re-connect and adjust the supplementary governing device.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Remove the high-speed spring retainer cover.

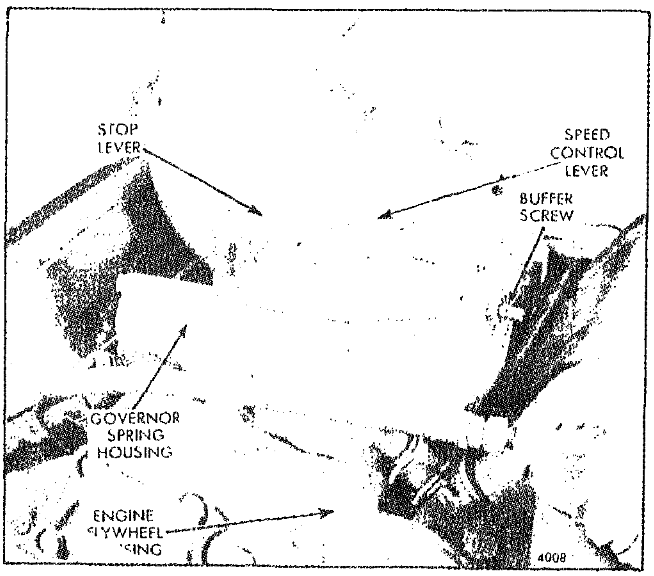


Fig. 1 - Limiting Speed Governor Mounting

2. Back out the buffer screw (Fig. 9) until it extends approximately 5/8″ from the lock nut.

CAUTION: Do not back the buffer screw out beyond the limits given, or the control link lever may disengage the differential lever.

3. Start the engine and loosen the idle speed adjusting screw lock nut. Then adjust the idle screw (Fig. 8) to obtain the desired engine idle speed. Hold the screw and tighten the lock nut to hold the adjustment.

NOTE: The recommended idle speed for non-EPA certified engines is 500-600 rpm, but may vary with special engine applications.

4. Stop the engine, clean and remove the governor cover and the valve rocker covers. Discard the gaskets.

5. Start and run the engine, between 800 and 1000 rpm, by manual operation of the differential lever.

CAUTION: Do not overspeed the engine.

6. Check the gap between the low-speed spring cap, and the high-speed spring plunger with a .0015″ feeler gage. If the gap setting is incorrect, reset the gap

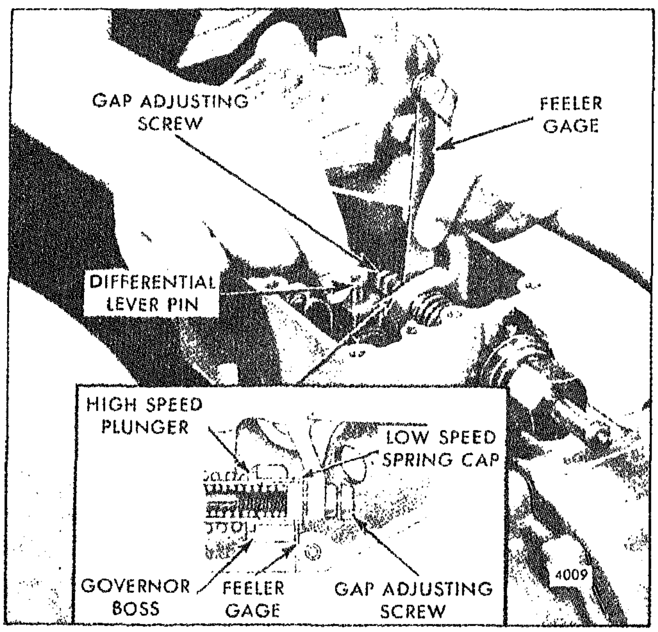


Fig. 2 - Adjusting Governor Gap

adjusting screw (Fig. 2). If the setting is correct, the .0015" movement can be seen by placing a few drops of oil into the governor gap and pressing a screw driver against the gap adjusting screw. Movement of the cap toward the plunger will force the oil from the gap in the form of a small bead.

7. Hold the gap adjusting screw and tighten the lock nut.

8. Recheck the gap and readjust if necessary.

9. Stop the engine and, using a new gasket, install the governor cover.

Position Injector Rack Control Levers

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector rack control levers with the engine at full-load will result in the following:

1. Speed control lever at the maximum speed position.
2. Governor low-speed gap closed.
3. High-speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the full-fuel position.

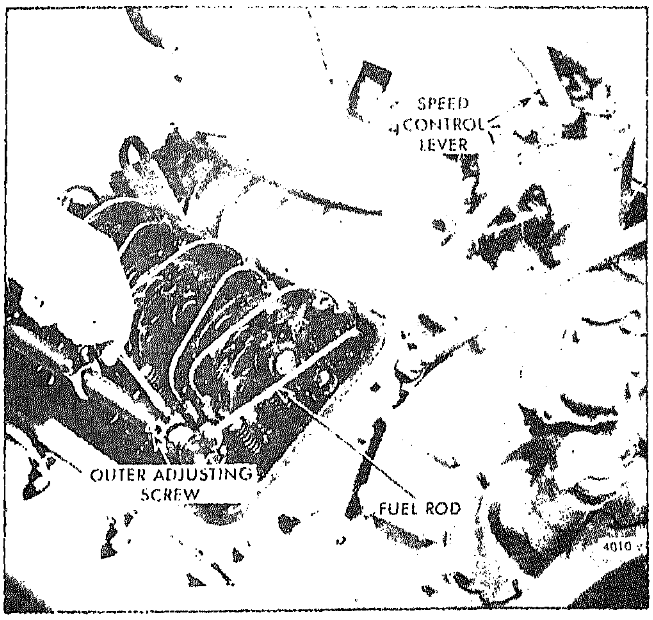


Fig. 3 - Positioning No. 3L Injector Rack Control Lever

The letters R or L indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 3L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until 1/2" of the threads (12-14 threads) project from the lock nut when the nut is against the high-speed plunger.

> **CAUTION:** A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

> **NOTE:** This adjustment lowers the tension of the low-speed spring so it can be easily compressed. This permits closing the low speed gap without bending the fuel rods or causing the *yield mechanism springs to yield or stretch.*

3. Back out the buffer screw approximately 5/8", if it has not already been done.

4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

5. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.

6. Move the speed control lever to the maximum speed position; hold it in that position with light finger pressure. Turn the inner adjusting screw on the

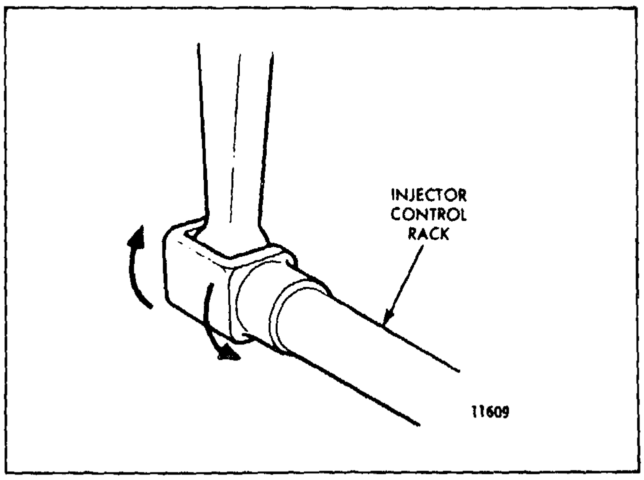


Fig. 4 · Checking Rotating Movement of Injector Control Rack

No. 3L injector rack control lever down as shown in Fig. 3 until a slight movement of the control tube lever is observed or a step-up in effort to turn the screw driver is noted. This will place the No. 3L injector in the full-fuel position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lbs** (3-4 Nm).

IMPORTANT: The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full-load.

7. To be sure of the proper rack adjustment, hold the speed control lever in the maximum speed position and press down on the injector rack with a screw driver or finger tip and note "rotating" movement of the injector control rack (Fig. 4) when the speed control lever is in the maximum speed position. Hold the speed control lever in the maximum speed position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Fig. 5) and when the pressure of the screw driver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly.

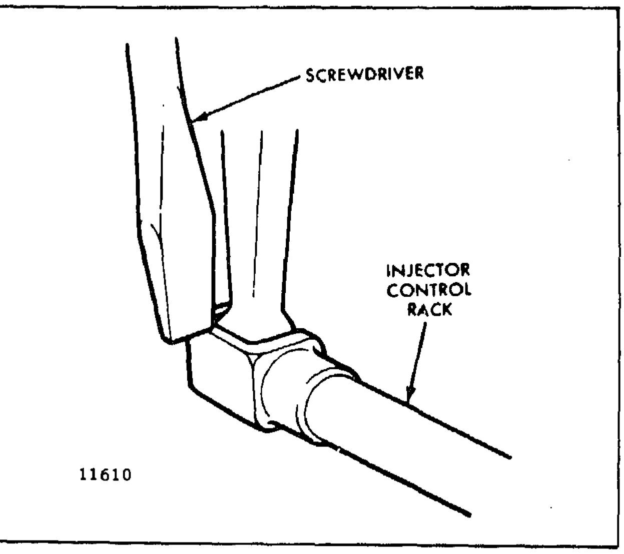


Fig. 5 - Checking Injector Control Rack "Spring"

The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel. To correct this condition, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 3R injector rack control lever as previously outlined in Step 6 for the No. 3L injector rack control lever.

10. Insert the clevis pin in the fuel rod and the left cylinder bank injector control tube lever. Repeat the check on the 3L and 3R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.

11. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rods and the injector control tube levers, hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube, and proceed as follows:

a. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the full-fuel position).

b. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.

c. While still holding the control tube lever in the full-fuel position, adjust the inner and outer adjusting screws to obtain the same condition as outlined in Step 7. Tighten the screws.

CAUTION: Once the No. 3L and No. 3R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

NOTE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended

torque of the adjusting screws is 24-36 **in-lbs** (3-4 Nm).

12. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 7. All of the control racks must have the same "spring" condition with the control tube lever in the full-fuel position.

13. Insert the clevis pin in the fuel rod and the injector control tube levers.

14. Turn the idle speed adjusting screw in until it projects 3/16" from the lock nut to permit starting the engine.

15. Use new gaskets and replace the valve rocker covers.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, set the maximum no-load speed as follows:

TYPE A GOVERNOR SPRINGS (Fig. 7):

1. Loosen the lock nut with a spanner wrench and back off the high-speed spring retainer several turns. Then start the engine and increase the speed slowly. If the speed exceeds the required no-load speed before the speed control lever reaches the end of its travel, back off the spring retainer a few additional turns.

2. With the engine at operating temperature and no-load on the engine, place the speed control lever in the maximum speed position. Turn the high-speed spring retainer in (Fig. 6) until the engine is operating at the recommended no-load speed. Use an accurate hand tachometer to determine the engine speed. The maximum no-load speed varies with the full-load operating speed.

3. Hold the spring retainer and tighten the lock nut.

TYPE B GOVERNOR SPRINGS (Fig. 7):

1. Start the engine and after it reaches normal operating temperature, remove the load from the engine.

2. Place the speed control lever in the maximum speed position and note the engine speed.

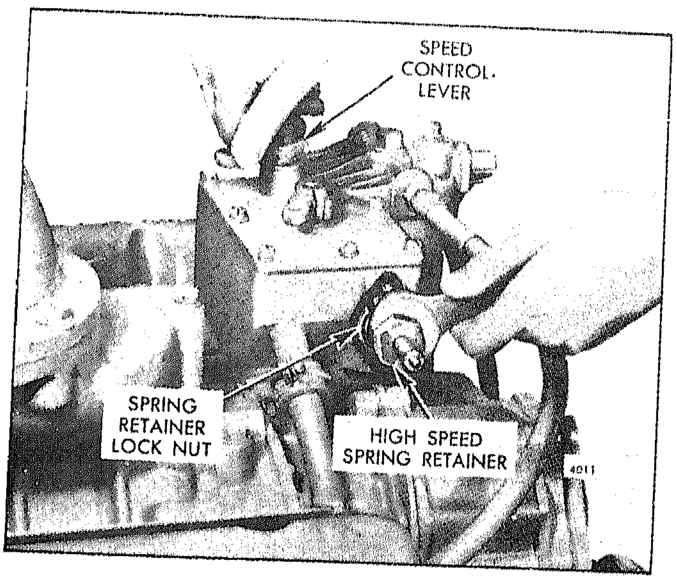


Fig. 6 - Adjusting Maximum No-Load Engine Speed

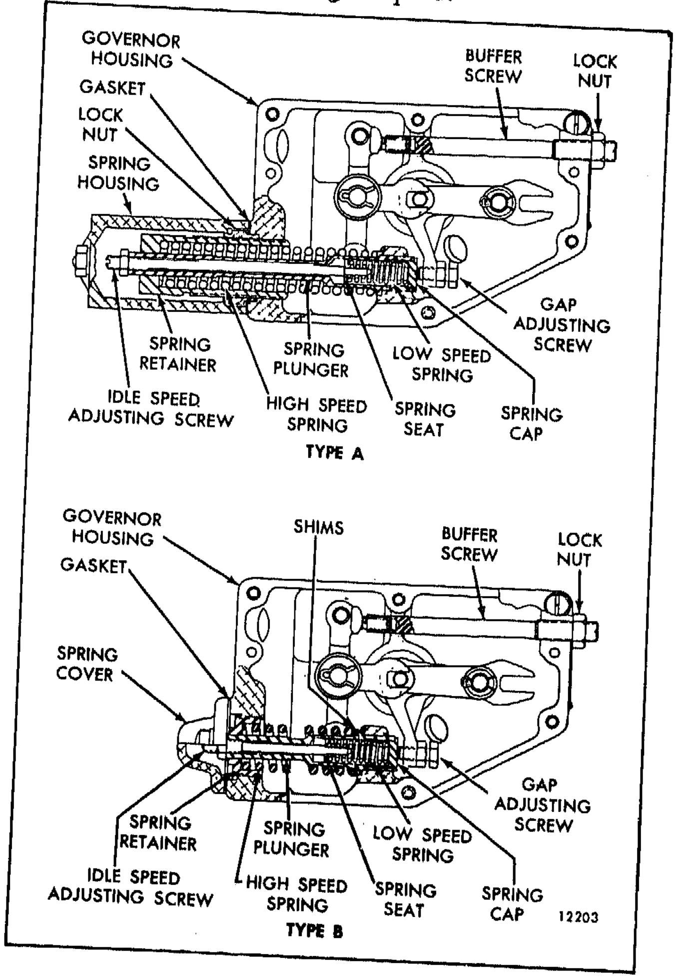


Fig. 7 - Governor Spring Assemblies

3. Stop the engine and, if necessary, adjust the no-load speed as follows:

a. Remove the high-speed spring retainer with tool J 5895 and withdraw the high-speed spring and plunger assembly.

CAUTION: To prevent the low-speed spring and cap from dropping into the governor, be careful not to jar the assembly while it is being removed.

b. Remove the high-speed spring from the high-speed spring plunger and add or remove shims as required to establish the desired engine no-load speed.

NOTE: For each .010″ in shims added, the engine speed will be increased approximately 10 rpm.

c. Install the high-speed spring on the plunger and install the spring assembly in the governor housing. Install the spring retainer in the governor housing and tighten it securely. The maximum no-load speed varies with the full-load operating speed desired.

d. Start the engine and recheck the no-load speed. Repeat the procedure as necessary to establish the no-load speed required.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 8) until the engine is operating at approximately 15 rpm below the recommended idle speed.

NOTE: The recommended idle speed for non-EPA certified engines is 500-600 rpm, but may vary with special engine applications.

If the engine has a tendency to stall during deceleration, install a new buffer screw. The current buffer screw uses a heavier spring and restricts the travel of the differential lever to the off (no-fuel) position.

2. Hold the idle screw and tighten the lock nut.

3. Install the high-speed spring retainer cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 9) so it contacts the differential lever as lightly as possible and still eliminates engine roll.

NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the lock nut.

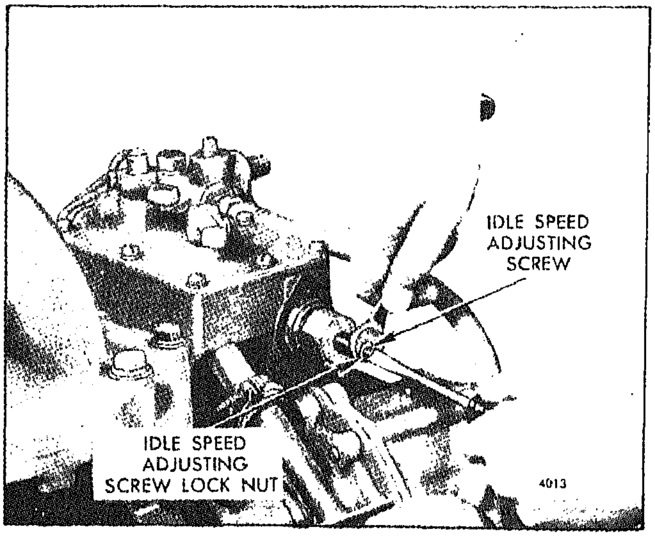


Fig. 8 - Adjusting Engine Idle Speed

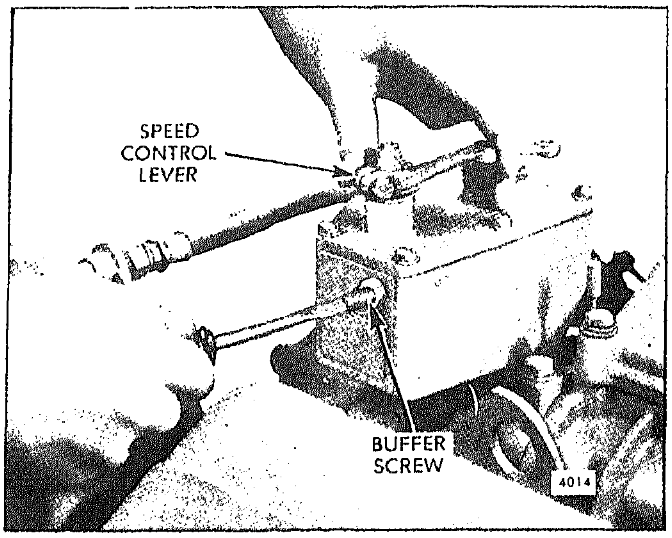


Fig. 9 - Adjusting Buffer Screw

VARIABLE SPEED MECHANICAL GOVERNOR (OPEN LINKAGE) AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINES

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor (Fig. 1) and the injector rack control levers.

Preliminary Governor Adjustments

1. Clean the governor linkage and lubricate the ball joints and bearing surfaces with clean engine oil.

2. Back out the buffer screw until it projects 9/16″ from the boss on the control housing.

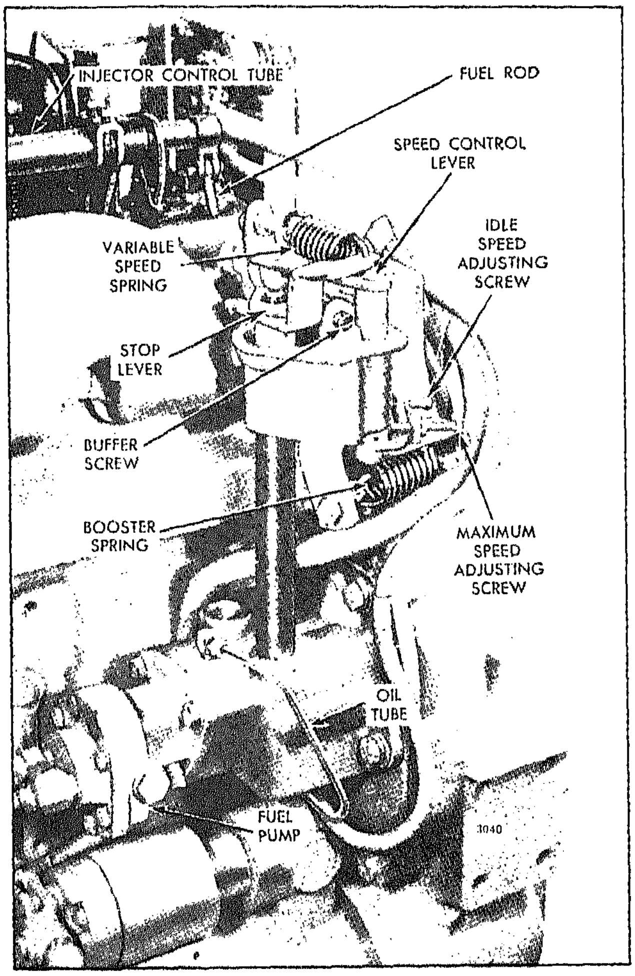


Fig. 1 - Variable Speed Open Linkage Governor Mounted on Engine

3. Back out the booster spring eye bolt until it is flush with the outer lock nut.

Adjust Variable Speed Spring Tension

1. Adjust the variable speed spring eye bolt until 1/8″ of the threads project from the outer lock nut (Fig. 2).

2. Tighten both lock nuts to retain the adjustment.

NOTE: This setting of the eye bolt will produce approximately 7% droop in engine speed from no-load to full-load.

Position Injector Rack Control Levers

The position of the injector control racks must be correctly set in relation to the governor. Their position

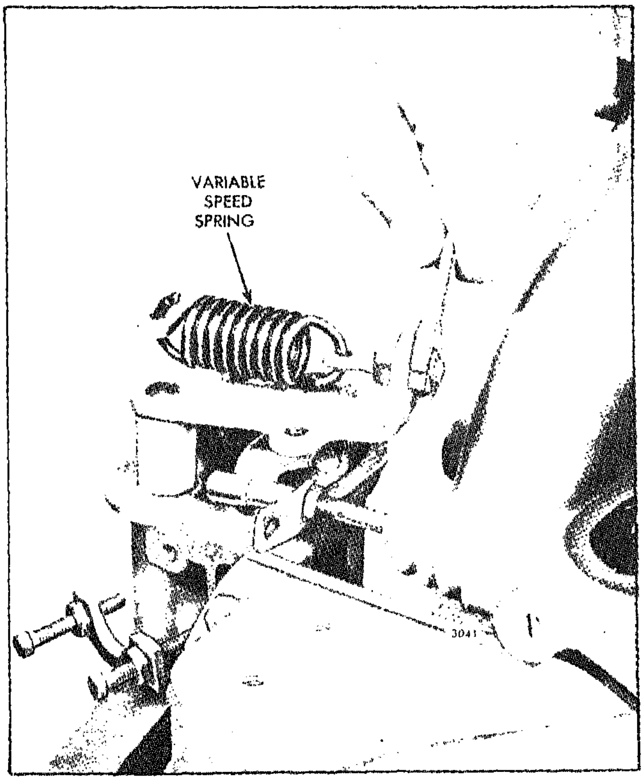


Fig. 2 - Adjusting Governor Spring Eye Bolt

determines the amount of fuel injected into each cylinder and ensures equal distribution of the load. Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Clean and remove the valve rocker cover. Discard the gasket.

2. Disconnect the fuel rod at the stop lever.

3. Loosen all of the inner and outer injector rack control lever adjusting screws. Be sure all of the injector rack control levers are free on the injector control tube.

4. Move the speed control lever to the maximum speed position.

5. Adjust the rear cylinder injector rack control lever adjusting screws (Fig. 3) until both screws are equal in height and tight on the injector control tube.

6. Move the rear injector control rack into the full-fuel position and note the clearance between the fuel rod and the cylinder head bolt. The clearance should be 1/32" or more. If necessary, readjust the injector rack adjusting screws until a clearance of at least 1/32" to 1/16" exists. Tighten the adjustment screws.

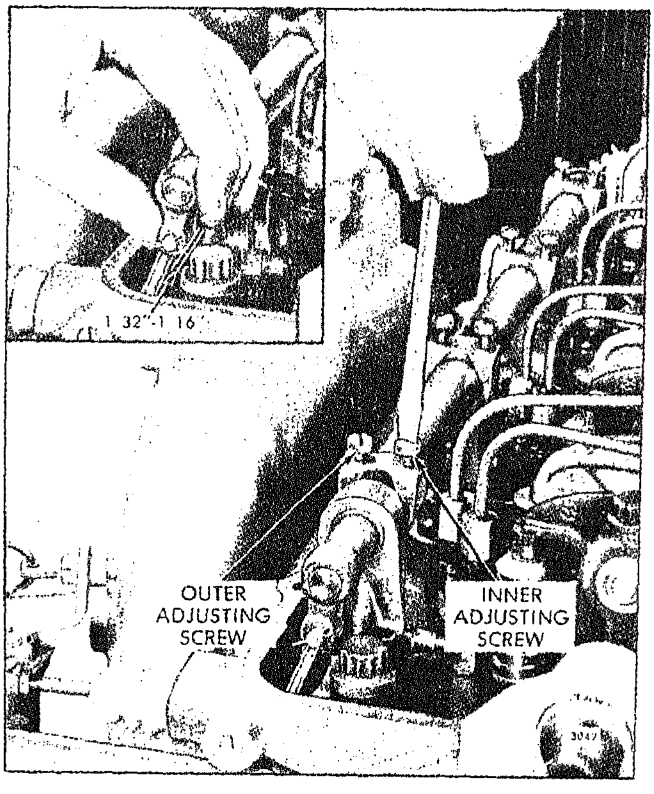


Fig. 3 - Adjusting Injector Rack Control Lever Adjusting Screws

7. Loosen the nut which locks the ball joint on the fuel rod. Hold the fuel rod in the full-fuel position and adjust the ball joint until it is aligned and will slide on the ball stud on the stop lever (Fig. 4). Position the shutdown cable clip and tighten the fuel rod lock nut to retain the adjustment.

8. Check the adjustment by pushing the fuel rod toward the engine and make sure the injector control rack is in the full-fuel position. If necessary, readjust the fuel rod.

9. Manually hold the rear injector rack in the full-fuel position, with the lever on the injector control tube, and turn the inner adjusting screw of the adjacent injector rack control lever down until the injector rack moves into the full-fuel position. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lbs** (3-4 Nm).

10. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector rack. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective control levers.

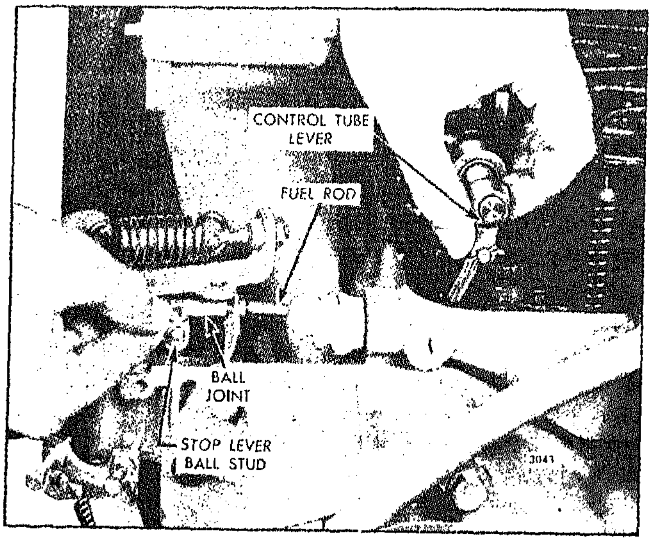


Fig. 4 - Adjusting Fuel Rod Length

11. Position the remaining injector rack control levers as outlined in Steps 9 and 10.

Adjust Maximum No-Load Speed

1. With the engine running, move the speed control lever to the maximum speed position. Use an accurate tachometer to determine the no-load speed of the engine.

> **NOTE:** Do not overspeed the engine.

2. Loosen the lock nut and adjust the maximum speed adjusting screw (Fig. 5) until the required no-load speed is obtained.

3. Hold the adjusting screw and tighten the lock nut.

Adjust Engine Idle Speed

1. Make sure the stop lever is in the run position and place the speed control lever in the idle position.

2. With the engine running at normal operating temperature, loosen the lock nut and turn the idle speed adjusting screw (Fig. 6) until the engine idles at the recommended speed. The recommended idle speed is 500 rpm. However, the idle speed may vary with special engine applications.

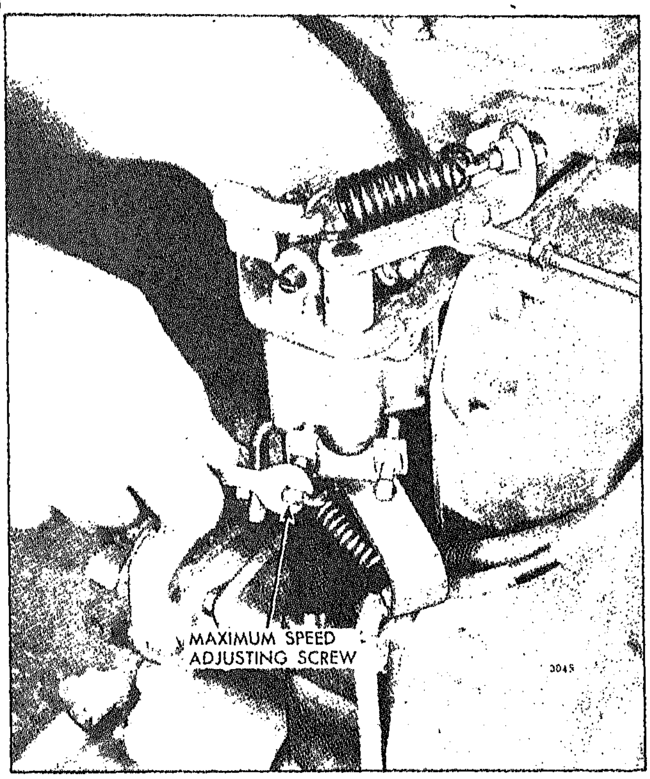


Fig. 5 - Adjusting Maximum No-Load Engine Speed

3. Hold the idle speed adjusting screw and tighten the lock nut.

Adjust Buffer Screw

1. With the engine running at idle speed, turn the buffer screw in (Fig. 7) so that it contacts the stop lever as lightly as possible and still eliminates engine roll.

> **NOTE:** Do not raise the engine idle speed more than 20 rpm with the buffer screw. Check the maximum no-load speed to make sure it has not increased over 25 rpm by the buffer screw setting.

Adjust Governor Booster Spring

The governor booster spring is used on some engines to reduce the force necessary to move the speed control lever from the idle speed position to the maximum speed position. Adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Reduce the tension on the booster spring, if not

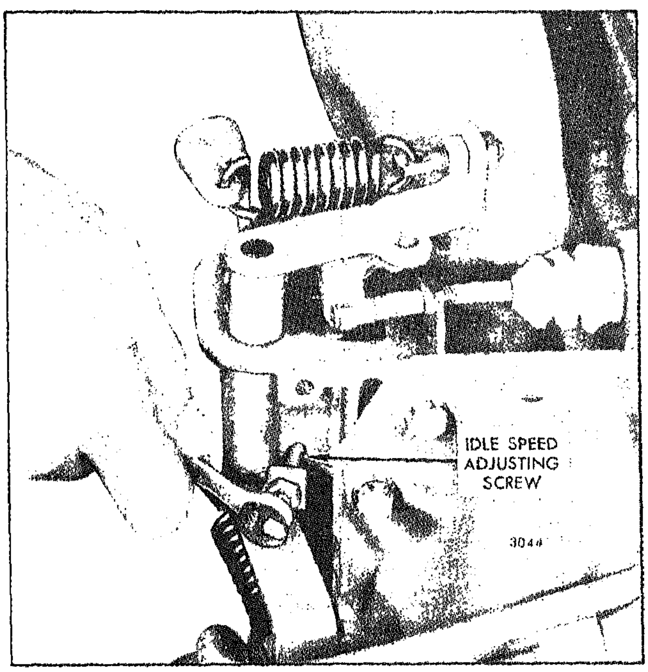


Fig. 6 - Adjusting Idle Speed

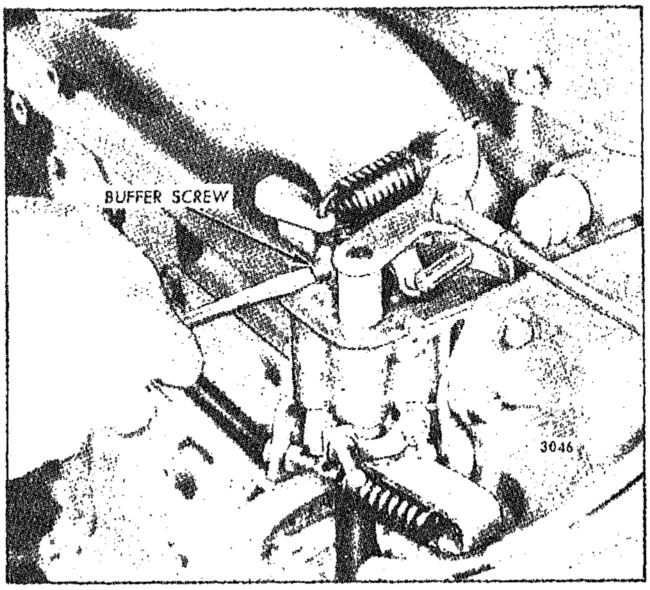


Fig. 7 - Adjusting Buffer Screw

previously performed, to the minimum by backing off the outer lock nut (Fig. 8) until the end of the booster spring eye bolt is flush with the end of the nut.

3. Adjust the eye bolt in the slot in the bracket so that an imaginary line through the booster spring will align with an imaginary center line through the speed control shaft. Secure the lock nuts on the eye bolt to retain the adjustment.

4. Move the speed control lever to the maximum speed position and note the force required. To reduce the force, back off the inner lock nut and tighten the outer lock nut to increase the tension on the booster spring.

> **NOTE:** Before tightening the lock nuts, reposition the booster spring as in Step 3.

The setting is correct when the speed control lever can be moved from the idle speed position to the maximum speed position with a constant force, while the engine is running, and when released it will return to the idle speed position.

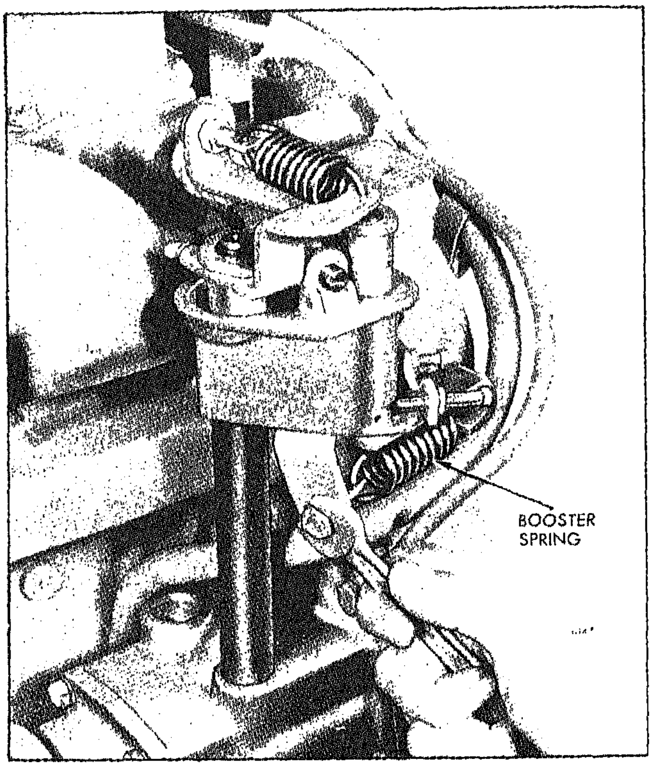


Fig. 8 - Adjusting Booster Spring

Adjust Engine Speed Droop

The adjustment of the spring tension as outlined under *Adjust Variable Speed Spring Tension* will result in approximately 7% droop from the maximum no-load speed to the full-load speed. This is the optimum droop setting for most applications. However, the droop may be changed as necessary for a particular engine application.

1. Lower the speed droop by increasing the spring tension.

2. Raise the speed droop by decreasing the spring tension.

> **NOTE:** A change in the variable speed spring tension will change the maximum no-load speed and the engine idle speed which must also be readjusted.

VARIABLE SPEED MECHANICAL GOVERNOR (ENCLOSED LINKAGE) AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINES

The single-weight variable speed governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

> **NOTE:** Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

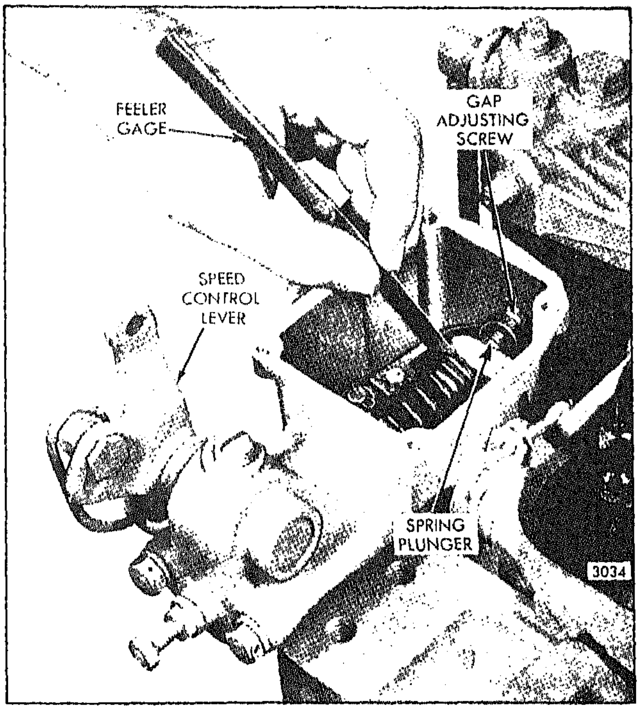


Fig. 1 - Checking Governor Gap

1. Disconnect any linkage attached to the governor levers.

2. Back out tne buffer screw until it extends approximately 5/8″ from the lock nut.

3. Clean and remove the governor cover and valve rocker cover. Discard the gaskets.

4. Place the spee control lever (Fig. 1) in the maximum speed position.

5. Insert a .006″ feeler gage between the spring plunger and the plunger guide as shown in Fig. 1. If required, loosen the lock nut and turn the gap adjusting screw in or out until a slight drag is noted on the feeler gage.

6. Hold the adjusting screw and tighten the lock nut. Check the gap and readjust if necessary.

7. Use a new gasket and install the governor cover as follows:

a. Place the cover on the governor housing, with the

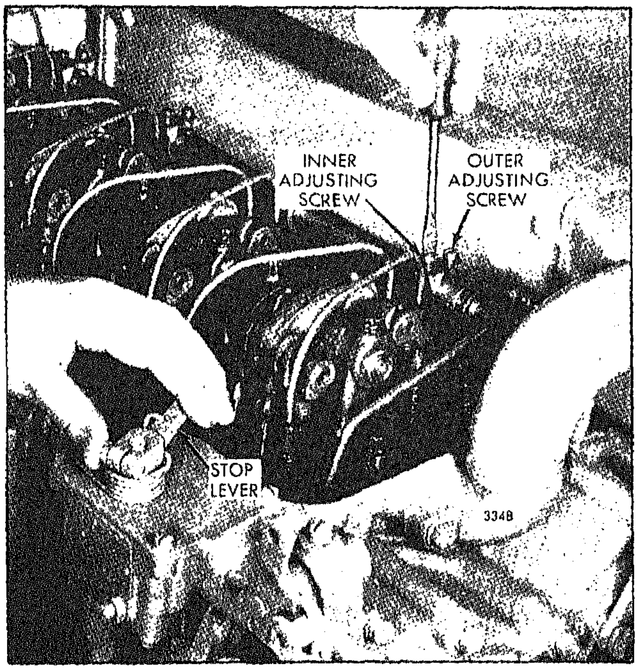


Fig. 2 - Positioning the Rear Injector Rack Control Lever

pin in the throttle shaft assembly entering the slot in the differential lever.

b. Install the four cover screws and lock washers finger tight.

c. Pull the cover assembly in a direction away from the engine, to take up the slack, and tighten the cover screws.

NOTE: This step is required since no dowels are used to locate the cover on the housing.

Position Injector Rack Control Levers

The position of the injector control rack levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load. Properly positioned injector control rack levers with the engine at full-load will result in the following:

1. Speed control lever at the maximum speed position.

2. Stop lever in the RUN position.

3. Injector fuel control racks in the full-fuel position.

Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Loosen all of the inner and outer injector rack control lever adjusting screws (Fig. 2). Be sure all of the levers are free on the injector control tube.

2. Move the speed control lever to the maximum speed position.

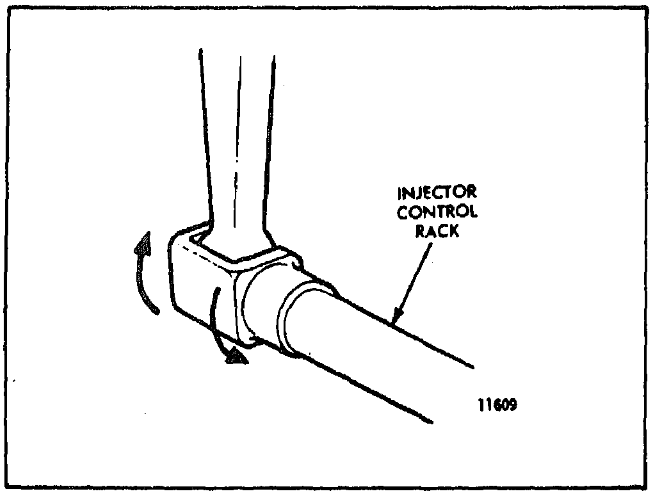


Fig. 3 - Checking Rotating Movement of Injector Control Rack

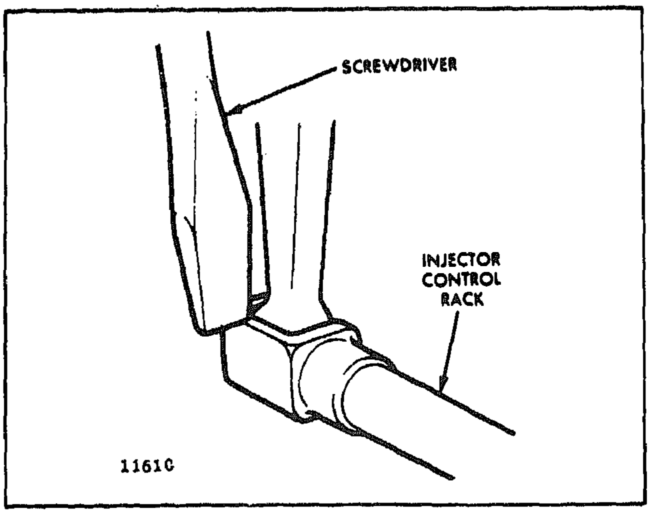


Fig. 4 - Checking Injector Control Rack "Spring"

3. Move the stop lever to the RUN position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the rear injector rack control lever down until a slight movement of the control tube is observed or a step-up in effort to turn the screw driver is noted. This will place the rear injector rack in the full-fuel position. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws. This should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 in-lbs (3-4 Nm).

4. To be sure of proper rack adjustment, hold the stop lever in the RUN position and press down on the injector rack with a screw driver or finger tip and note "rotating" movement of the injector control rack (Fig. 3). Hold the stop lever in the RUN position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Fig. 4) and, when the pressure of the screw driver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw. The setting is too tight if, when moving the stop lever from the STOP to the RUN position, the injector rack becomes tight before the stop lever reaches the end of its travel. This will result in a step-up in effort

required to move the stop lever to the RUN position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is found to be too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

5. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rod and the injector control tube lever, hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

6. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector rack. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective control levers.

7. Position the remaining injector rack control levers as outlined in Steps 4, 5 and 6.

8. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 4. All of the control racks must have the same "spring" condition with the control tube lever in the full-fuel position.

9. Insert the clevis pin in the fuel rod and the injector control tube levers.

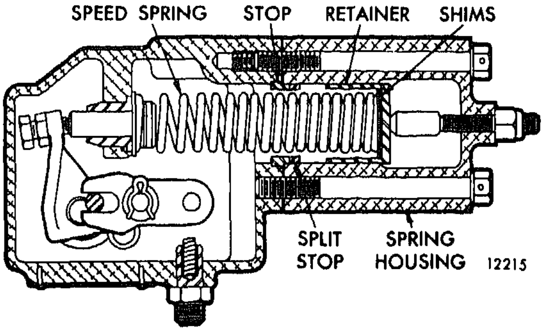


Fig. 5 - Locating of Shims and Stops

10. Use a new gasket and replace the valve rocker cover.

Adjust Maximum No-Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the option plate, the maximum no-load speed may be set as follows:

Start the engine and, after it reaches normal operating temperature, determine the maximum no-load speed of the engine with an accurate tachometer. Then stop the engine and make the following adjustments, if required.

1. Refer to Fig. 8 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the variable speed spring housing and the variable speed spring retainer located inside of the housing.

3. Refer to Table 1 and determine the stops or shims required for the desired full-load speed. Do not use more than four thick and one thin shim. A split stop can only be used with a solid stop (Fig. 5).

4. Install the variable speed spring retainer and housing and tighten the two bolts.

5. Connect the booster spring and stop lever spring. Start the engine and recheck the maximum no-load speed.

6. If required, add shims to obtain the necessary operating speed. For each .001" in shims added, the operating speed will increase approximately 2 rpm.

IMPORTANT: If the maximum no-load speed is raised or lowered more than 50 rpm by the

Full Load Speed RPM	STOPS		SHIMS
	Solid Ring	Split Ring	
2575-2800	0	0	As Required
2101-2575	1	0	As Required
1701-2100	1	1	As Required
1200-1700	1	2	As Required

TABLE 1

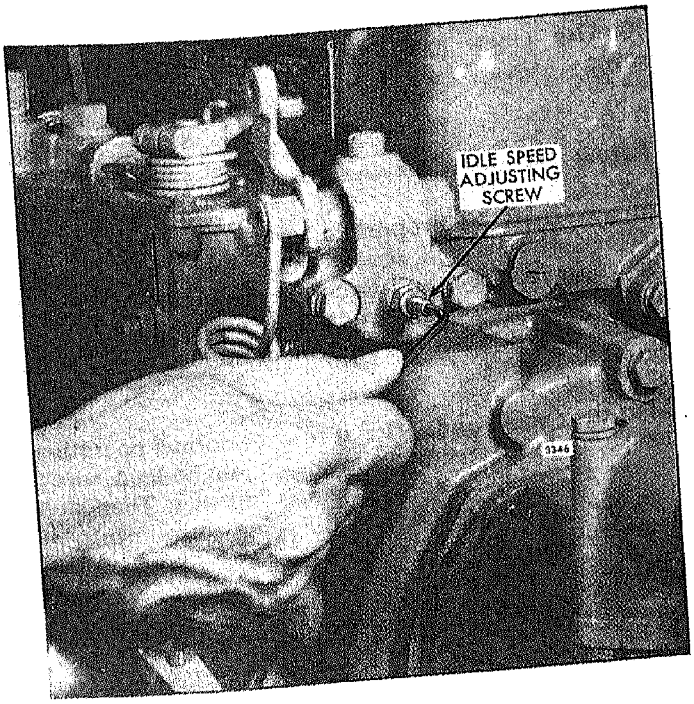


Fig. 6 - Adjusting Idle Speed

installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

NOTE: Governor stops are used to limit the compression of the governor spring which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

1. Place the stop lever in the RUN position and the speed control lever in the IDLE position.

2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

3. Loosen the lock nut and turn the idle speed adjusting screw (Fig. 6) until the engine is operating at approximately 15 rpm below the recommended idle speed.

The recommended idle speed is 550 rpm, but may vary with special engine applications.

4. Hold the idle speed adjusting screw and tighten the lock nut.

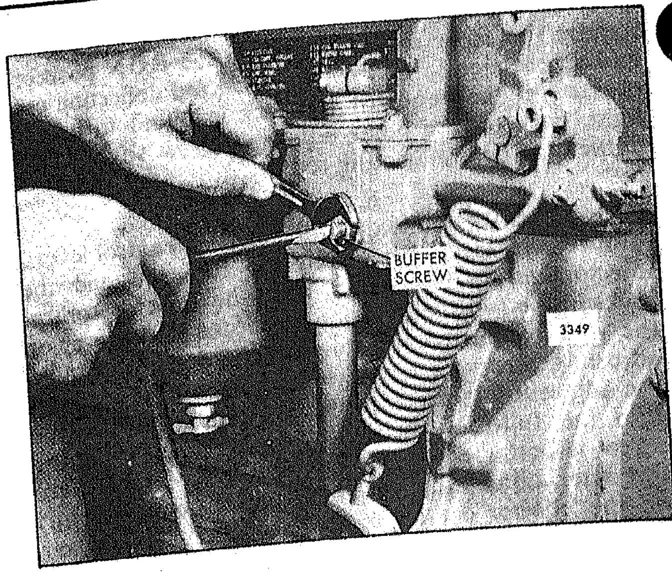


Fig. 7 - Adjusting Buffer Screw

Adjust Buffer Screw

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 7) so that it contacts the differential lever as lightly as possible and still eliminates engine roll.

NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Hold the buffer screw and tighten the lock nut.

Adjust Booster Spring

With the engine idle speed adjusted, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Refer to Fig. 8 and loosen the booster spring retaining nut on the speed control lever. Loosen the lock nuts on the eye bolt at the opposite end of the booster spring.

3. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the idle speed position) of an imaginary line through the bolt, lever shaft and eye bolt. Hold the bolt and tighten the lock nut.

4. Start the engine and move the speed control lever to the maximum speed position and release it. The lever should return to the idle speed position. If it does not, reduce the tension on the booster spring. If it does, continue to increase the spring tension until the point is reached where it will not return to idle. Then reduce

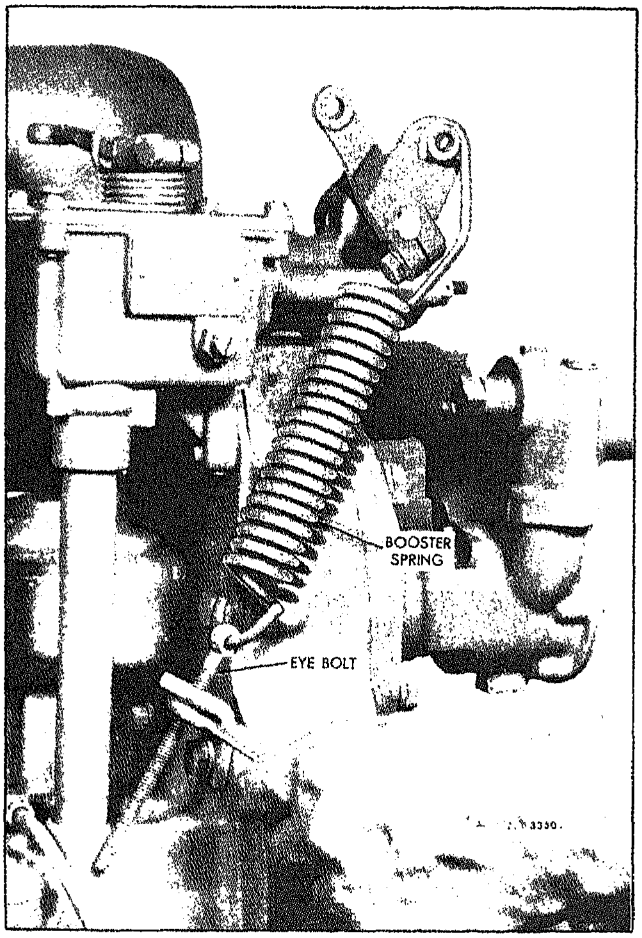


Fig. 8 - Adjusting Booster Spring

the spring tension until the lever does return to idle and tighten the lock nuts on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.

5. Connect the linkage to the governor levers.

VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

6V-53 ENGINE

The variable speed mechanical governor assembly is mounted at the rear of the 6V engine, between the flywheel housing and the blower (Fig. 1). The governor is driven by the right-hand blower rotor drive gear.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

> **NOTE:** Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device.

Adjust Governor Gap

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

1. Disconnect any linkage attached to the governor levers.

2. Back out the buffer screw until it extends approximately 5/8" from the lock nut.

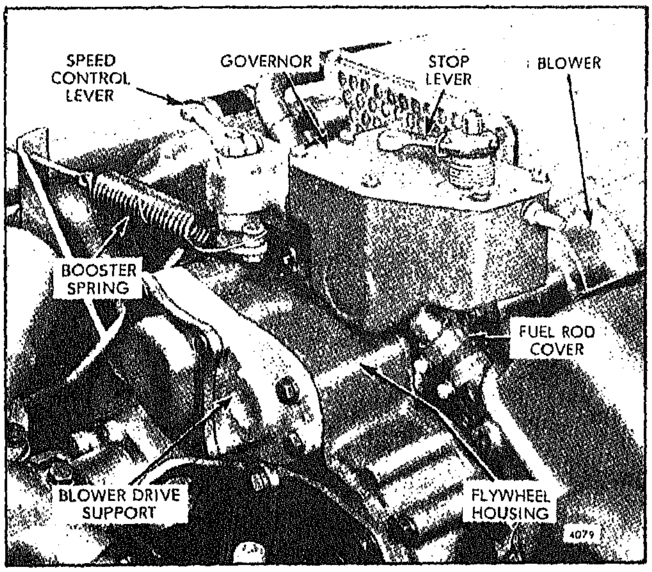


Fig. 1 · Variable Speed Governor Mounting

3. Clean and remove the governor cover and the valve rocker covers. Discard the gaskets.

4. Place the speed control lever in the maximum speed position.

5. Insert a .006" feeler gage between the spring plunger and the plunger guide as shown in Fig. 2. If required, loosen the lock nut and turn the adjusting screw in or out until a slight drag is noted on the feeler gage.

6. Hold the adjusting screw and tighten the lock nut. Check the gap and readjust if necessary.

7. Use a new gasket and install the governor cover.

Position Injector Rack Control Levers

The position of the injector control racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector rack control levers with the engine at full-load will result in the following:

1. Speed control lever at the maximum speed position.

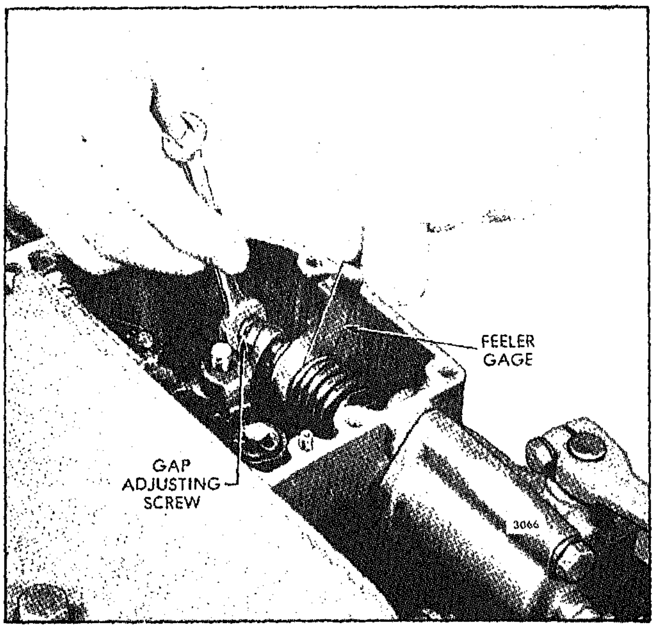


Fig. 2 · Adjusting Governor Gap

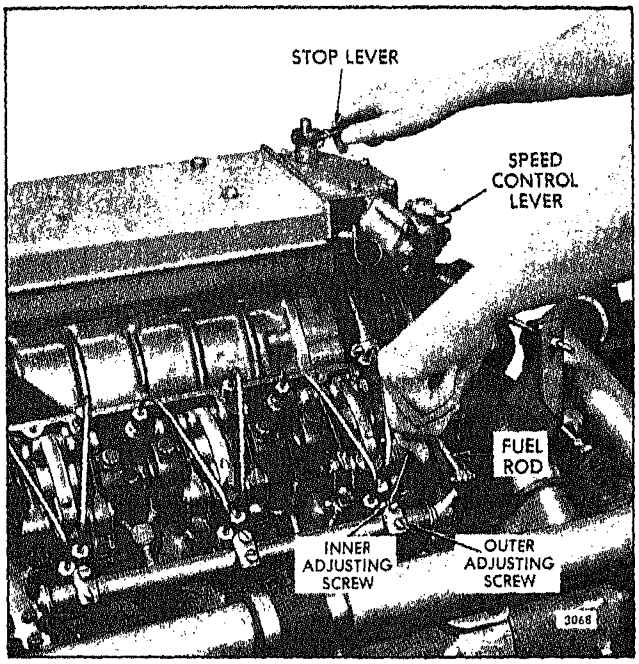


Fig. 3 - Positioning No. 3L Injector Rack Control Lever

2. Stop lever in the RUN position.

3. Injector fuel control racks in the full-fuel position.

The letters R or L indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 3L injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

2. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.

3. Move the speed control lever to the maximum speed position.

4. Move the stop lever to the *run* position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 3L injector rack control lever down (Fig. 3) until a slight movement of the control tube is observed, or a step-up in effort to turn the screw driver is noted. This will place the No. 3L injector rack in the *full-fuel* position. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

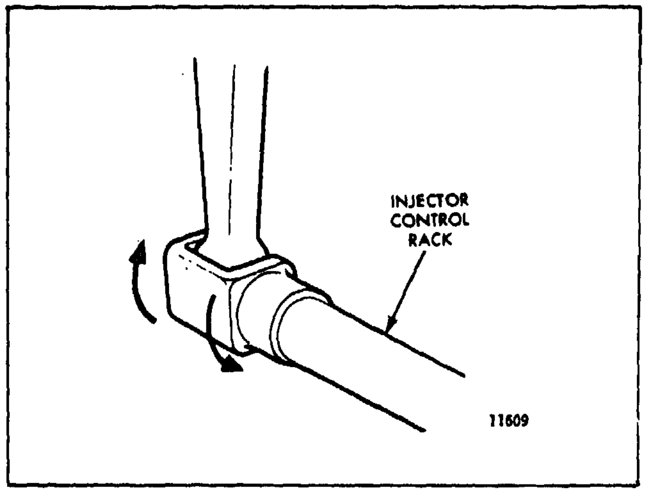


Fig. 4 - Checking Rotating Movement of Injector Control Rack

NOTE: Overtightening the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lb** (3-4 Nm).

The above steps should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

5. To be sure of proper rack adjustment, hold the stop

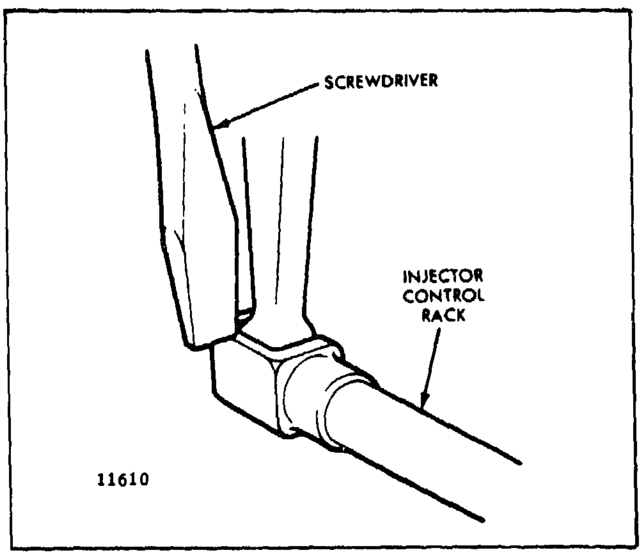


Fig. 5 - Checking Injector Control Rack "Spring"

lever in the *run* position and press down on the injector rack with a screw driver or finger tip and note the "rotating" movement of the injector control rack (Fig. 4). Hold the stop lever in the *run* position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Fig. 5) and when the pressure of the screw driver is released, the control rack should "spring" back upward. If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw. The setting is too tight if, when moving the stop lever from the *stop* to the *run* position, the injector rack becomes tight before the governor stop lever reaches the end of its travel. This will result in a step-up in effort required to move the stop lever to the *run* position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is found to be too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

6. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

7. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 3R injector rack control lever as previously outlined in Step 4 for the No. 3L control lever.

8. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the 3L and 3R injector rack control levers as outlined in Step 5. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.

9. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rods and the injector control tube levers, hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube and proceed as follows:

a. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the full-fuel position).

b. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.

c. While still holding the control tube lever in the full-fuel position, adjust the inner and outer adjusting screws to obtain the same condition as outlined in Step 5. Tighten the screws.

CAUTION: Once the No. 3L and No. 3R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

10. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 5. All of the control racks must have the same "spring" condition with the control tube lever in the full-fuel position.

11. Insert the clevis pin in the fuel rods and the injector control tube levers.

12. Use new gaskets and install the valve rocker covers.

Adjust Maximum No-Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, the maximum no-load speed may be set as follows:

Start the engine and after it reaches normal operating temperature, determine the maximum no-load speed of the engine with an accurate tachometer. Then stop the engine and make the following adjustments, if required.

1. Refer to Fig. 9 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the variable speed spring housing and the spring retainer, located inside of the housing, from the governor housing.

3. Refer to Table 1 and determine the stops or shims required for the desired full-load speed. A split stop can only be used with a solid stop (Fig. 6).

4. Install the variable speed spring retainer and housing and tighten the two bolts.

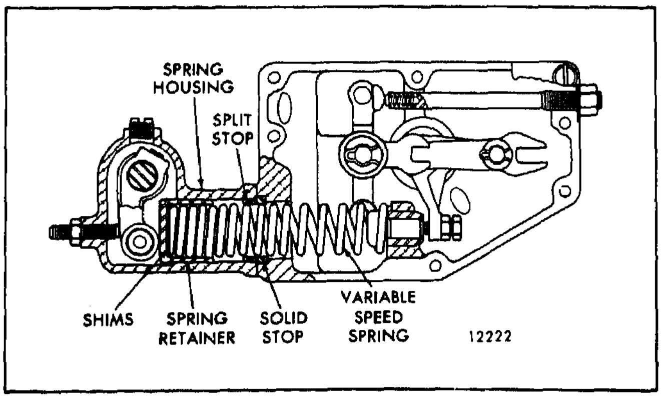


Fig. 6 - Location of Shims and Stops

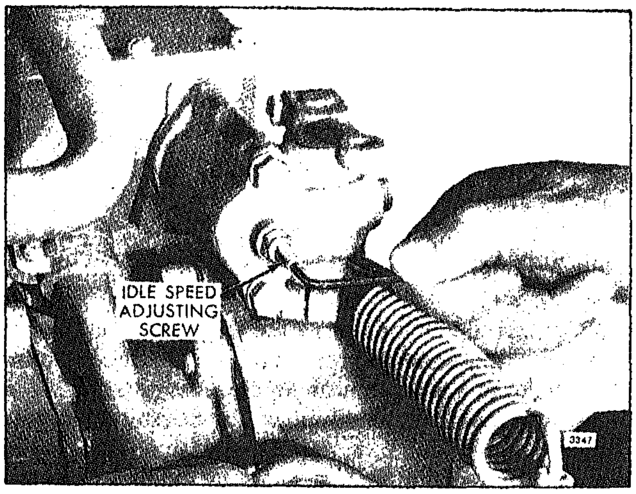


Fig. 7 - Adjusting Idle Speed

Full-Load Speed	Stops		Shims*
	Solid	Split	
1200-2100	1	1	As Required
2100-2500	1	0	As Required
2500-2800	0	0	As Required

*Maximum amount of shims .325"

TABLE 1

5. Connect the booster spring and the stop lever spring. Start the engine and recheck the maximum no-load speed.

6. If required, add shims to obtain the necessary operating speed. For each .001" in shims added, the operating speed will increase approximately 2 rpm.

> **IMPORTANT:** If the maximum no-load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

> **NOTE:** Governor stops are used to limit the compression of the governor spring, which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

1. Place the stop lever in the *run* position and the speed control lever in the *idle* position.

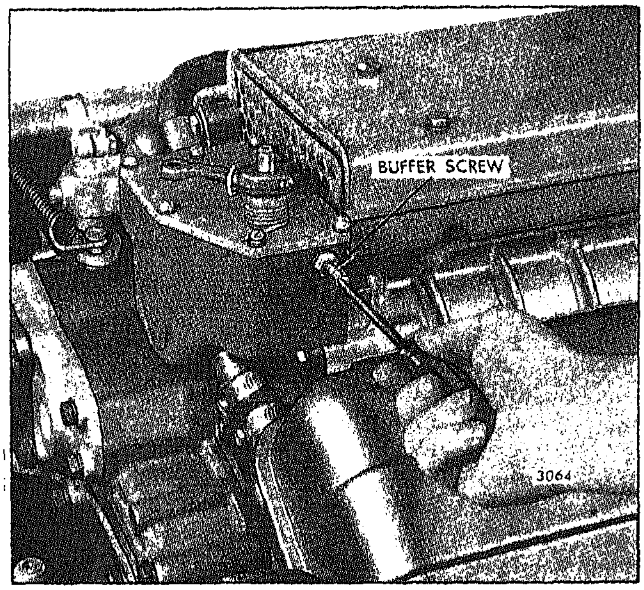


Fig. 8 - Adjusting Buffer Screw

2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

3. Loosen the lock nut and turn the idle speed adjusting screw (Fig. 7) until the engine is operating at approximately 15 rpm below the recommended idle speed. The recommended idle speed is 550 rpm, but may vary with special engine applications.

4. Hold the idle speed adjusting screw and tighten the lock nut.

Adjust Buffer Screw

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 8) so that it contacts the differential lever as lightly as possible and still eliminates engine roll.

> **NOTE:** Do not raise the engine idle speed more than 15 rpm with the buffer screw.

2. Hold the buffer screw and tighten the lock nut.

Adjust Booster Spring

With the idle speed adjusted, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Refer t

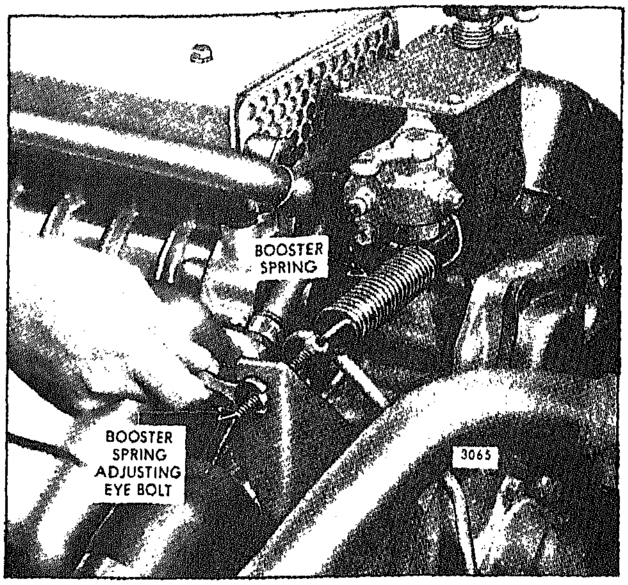


Fig. 9 - Adjusting Booster Spring

retaining nut on the speed control lever. Loosen the lock nuts on the eye bolt at the opposite end of the booster spring.

3. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the idle speed position) of an imaginary line through the bolt, lever shaft and eye bolt. Hold the bolt and tighten the lock nut.

4. Start the engine and move the speed control lever to the maximum speed position and release it. The speed control lever should return to the idle position. If it does not, reduce the tension on the booster spring. If the lever does return to the idle position, continue to increase the spring tension until the point is reached that it will not return to idle. Then reduce the tension until it does return to idle and tighten the lock nut on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.

5. Connect the linkage to the governor levers.

SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

ENGINE LOAD LIMIT DEVICE

Engines with mechanical governors may be equipped with a load limit device (Fig. 1) to reduce the maximum horsepower.

This device consists of a load limit screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a load limit lever clamped to the injector control tube.

The load limit device is located between the No. 2 and No. 3 cylinders of a three or four cylinder engine or between the No. 1 and No. 2 cylinders of *each* cylinder head on a V-type engine. However, when valve rocker covers with a breather are used, the load limit device is installed between the No. 1 and No. 2 cylinders on in-line engines and between the No. 2 and No. 3 cylinders on V-type engines to avoid interference with the rocker cover baffles.

When properly adjusted for the maximum horsepower desired, this device limits the travel of the injector control racks and thereby the fuel output of the injectors.

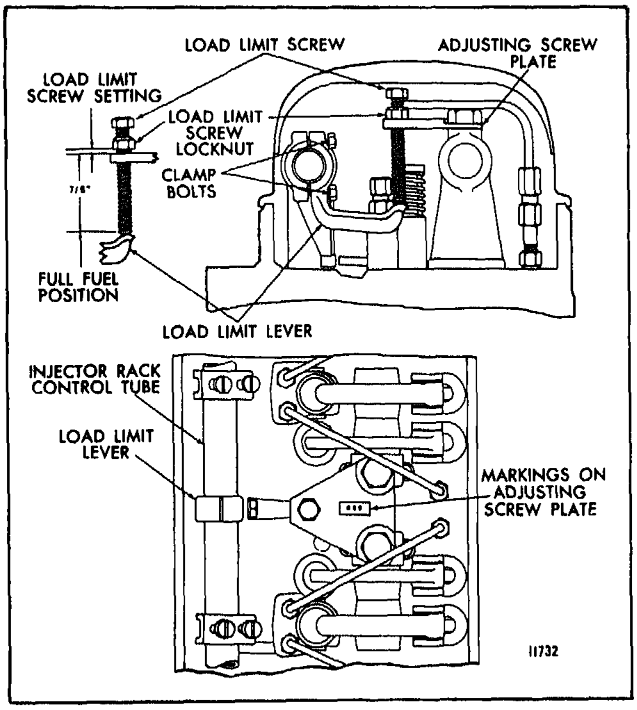


Fig. 1 - Engine Load Limit Device

Adjustment

After the engine tune-up is completed, make sure the load limit device is properly installed as shown in Fig. 1. Make sure the counterbores in the adjusting screw plate are up. The rocker arm shaft bracket bolts which fasten the adjusting screw plate to the brackets are tightened to 50-55 lb-ft (68-75 Nm) torque. Then adjust the load limit device, on each cylinder head, as follows:

1. Loosen the load limit screw lock nut and remove the screw.

2. Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.

3. With the screw out of the plate, adjust the load limit screw lock nut so the bottom of the lock nut is 7/8" from the bottom of the load limit screw (Fig. 1) for the initial setting.

4. Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.

4. Thread the load limit screw into the adjusting screw plate until the lock nut *bottoms* against the top of the plate.

5. Hold the injector rack control tube in the full-fuel position and place the load limit lever against the bottom of the load limit screw. Then tighten the load limit lever clamp bolts.

6. Check to ensure that the injector racks will just go into the full-fuel position -- readjust the load limit lever if necessary.

7. Hold the load limit screw to keep it from turning, then *set* the lock nut until the distance between the bottom of the lock nut and the top of the adjusting screw plate corresponds to the dimension (or number of turns) stamped on the plate. Each full turn of the screw equals .042", or .007" for each flat on the hexagon head.

> **NOTE:** If the plate is not stamped, adjust the load limit screw while operating the engine on a dynamometer test stand and note the number of turns required to obtain the desired horsepower. Then stamp the plate accordingly.

8. Thread the load limit screw into the plate until the lock nut *bottoms* against the top of the plate. Be sure the nut turns with the screw.

9. Hold the load limit screw to keep it from turning, then tighten the lock nut to secure the setting.

THROTTLE DELAY MECHANISM

The throttle delay mechanism is used to retard full-fuel injection when the engine is accelerated. This reduces exhaust smoke and also helps to improve fuel economy.

The throttle delay mechanism (Fig. 2) is installed between the No. 1 and No. 2 cylinders on three cylinder engines, between the No. 2 and No. 3 cylinders on four cylinder engines, or between the No. 1 and No. 2 cylinders on the right-bank cylinder head of V-type engines. It consists of a special rocker arm shaft bracket (which incorporates the throttle delay cylinder), a piston, throttle delay lever, connecting link, oil supply plug, ball check valve and U-bolt.

A yield lever and spring assembly replaces the standard lever and pin assembly on the rear end of the injector control tube on In-line engines (Fig. 3). A yield lever replaces the standard operating lever in the governor of the 6V-53 engine (Fig. 4).

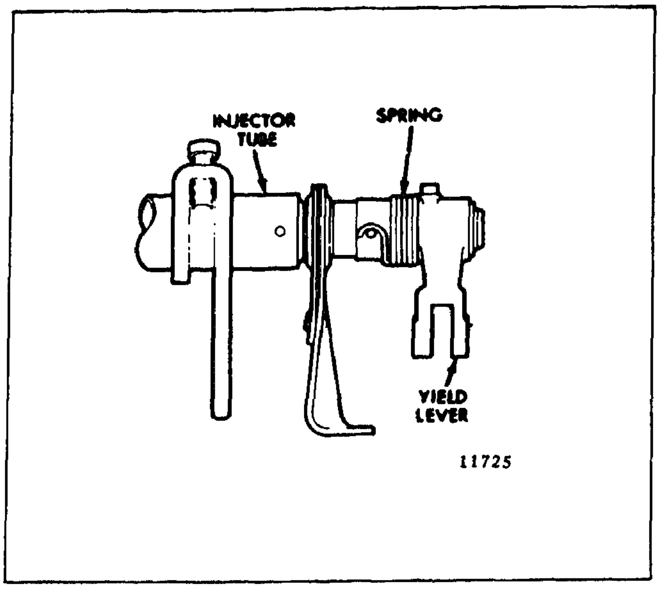


Fig. 3 - Throttle Delay Yield Lever (In-Line Engine)

Operation

Oil is supplied to a reservoir above the throttle delay cylinder through a special plug in the drilled oil passage in the rocker arm shaft bracket (Fig. 2). As the injector racks are moved toward the no-fuel position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further movement of the piston uncovers an opening which permits oil from the reservoir to enter the cylinder and displace the air. When the engine is accelerated, movement of the injector racks toward the full-fuel position is momentarily retarded while the piston expels the oil from the cylinder through a .016″ orifice. To permit full accelerator travel, regardless of the retarded injector rack position, a spring loaded yield lever or link assembly replaces the standard operating lever connecting link to the governor.

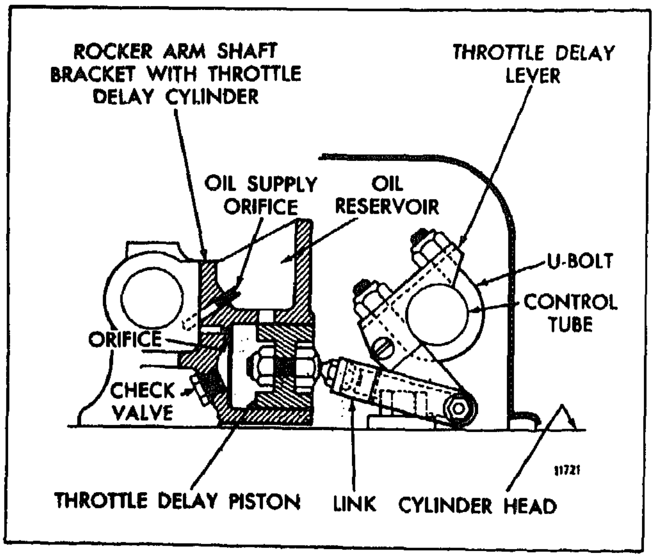


Fig. 2 - Throttle Delay Cylinder

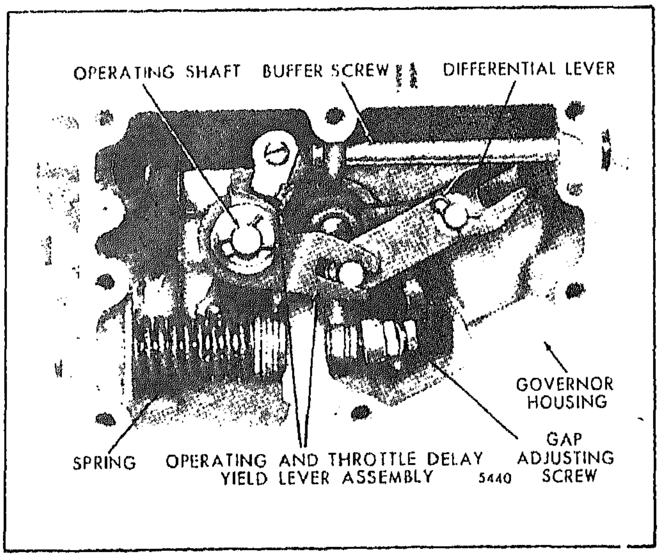


Fig. 4 - Throttle Delay Yield Lever (6V Engine)

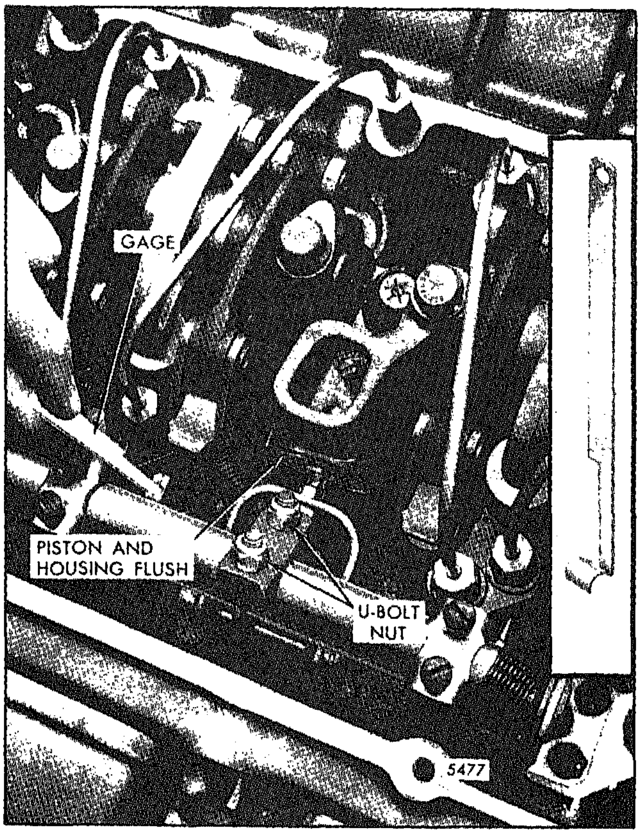


Fig. 5 - Adjusting Throttle Delay Cylinder

Inspection

When inspecting the throttle delay hydraulic cylinder, it is important that the check valve be inspected for wear. Replace the check valve if necessary.

To inspect the check valve, fill the throttle delay cylinder with diesel fuel oil and watch for check valve leakage while moving the engine throttle from the idle position to the full fuel position.

Adjustment

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U-bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be re-adjusted. With the engine stopped, proceed as follows:

1. Refer to Fig. 5 and insert gage J 23190 (.454" setting) between the injector body and the shoulder on the injector rack. Then exert a light pressure on the injector control tube in the direction of full fuel.

2. Align the throttle delay piston so it is flush with the edge of the throttle delay cylinder.

3. Tighten the U-bolt on the injector control tube and remove the gage.

4. Move the injector rack from the no-fuel to full-fuel to make sure it does not bind.

ADJUSTMENT OF MECHANICAL GOVERNOR SHUTDOWN SOLENOID

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel.

The solenoid plunger can be properly aligned to the governor stop lever as follows:

1. Remove the bolt connecting the rod end eye (variable speed governor), or the right angle clip (limiting speed governor) to the stop lever (Figs. 6 and 7). Align and clamp the lever to the shutdown shaft in such a way that, at its mid-travel position, it is perpendicular to the solenoid plunger. This assures that the linkage will travel as straight as possible. The solenoid plunger has available 1/2" travel which is more than adequate to move the injector control racks from the full-fuel to the complete no-fuel position and shutdown will occur prior to attaining complete travel.

2. With the stop lever in the *run* position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt is installed. The oversize hole in the eye or clip will thereby permit the solenoid to start closing the air gap, with a resultant build-up of pull-in force prior to initiating stop lever movement.

3. The bolt through the rod end eye or the right angle clip should be locked to the stop lever and adjusted to a height that will permit the eye or clip to float vertically. The clearance above and below the eye or clip and the bolt head should be approximately 1/32" minimum.

> **NOTE:** The lock nut can be either on top of or below the stop lever.

4. Move the lever to the *stop* position and observe the plunger for any possible bind. If necessary, loosen the

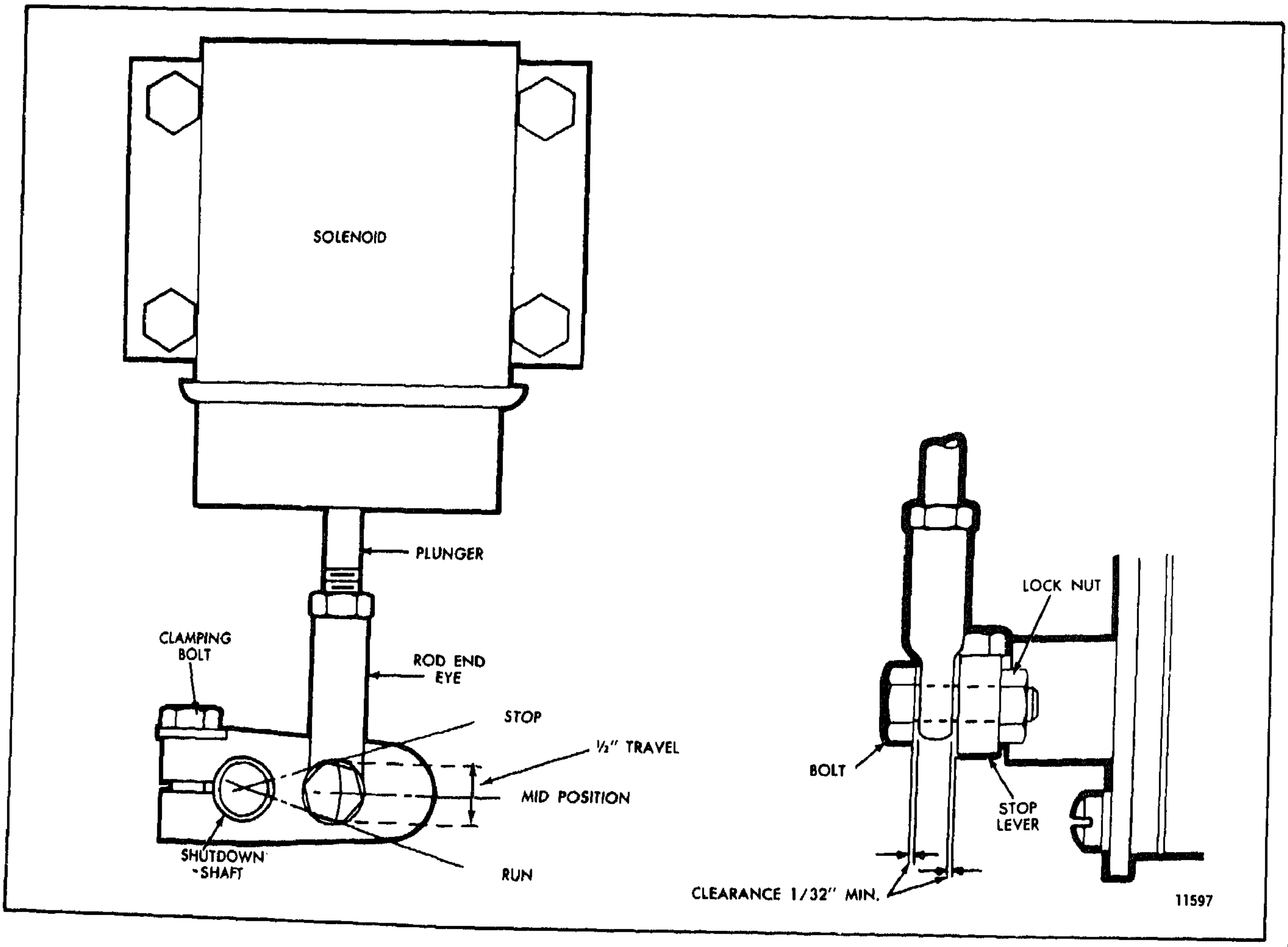


Fig. 6 - Typical Variable Speed Governor Lever Position

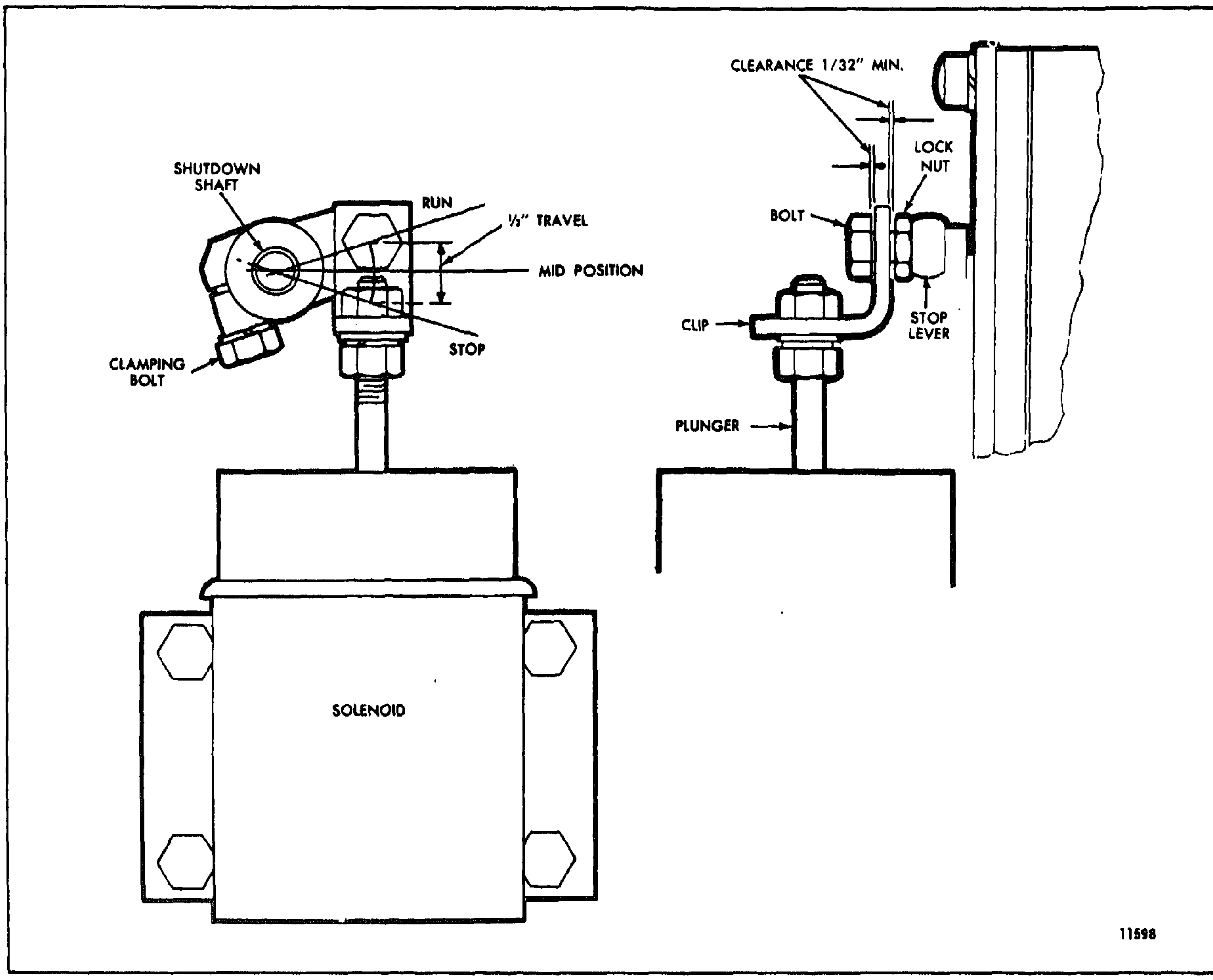


Fig. 7 · Typical Limiting Speed Governor Lever Position

mounting bolts and realign the solenoid to provide free plunger motion.

HYDRAULIC GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINE

The hydraulic governor is mounted on the 3 and 4-53 engines as shown in Fig. 1. The terminal lever return spring and the fuel rod are attached to an external terminal shaft lever. The maximum fuel position of the governor load limit is determined by the internal governor terminal lever striking against a boss that projects from the governor cover.

Adjust engines having a hydraulic governor assembly after adjusting the exhaust valve clearance and timing the fuel injectors.

Adjust Fuel Rod and Injector Rack Control Levers

1. Adjust the inner and outer adjusting screws (Fig. 2) on the rear injector rack control lever until both screws are equal in height and tight on the control tube. Check the clearance between the fuel rod and the cylinder head casting (below the bolt) for at least 1/16" clearance when the injector rack is in the *full-fuel* position and the rack adjusting screws are tight. If the fuel rod contacts the bolt or cylinder head casting, readjust the screws to obtain the 1/16" clearance.

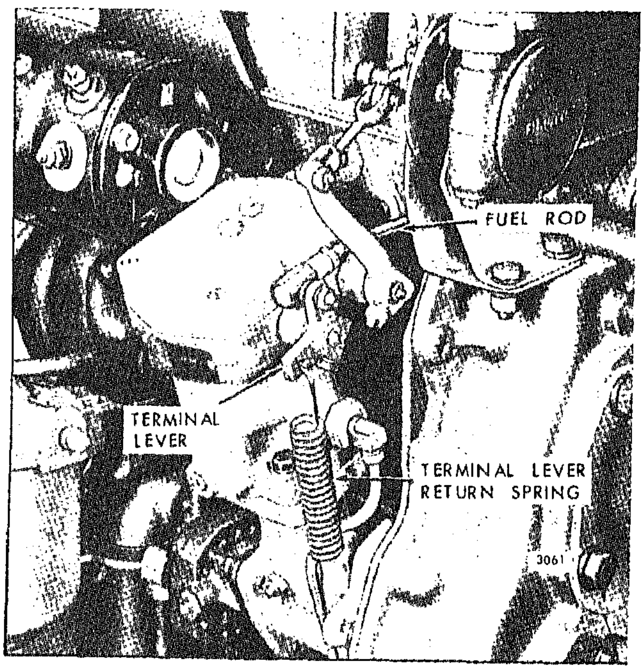


Fig. 1 - Hydraulic Governor Mounted on Engine

NOTE: Overtightening the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lbs** (3-4 Nm).

2. Remove the governor terminal lever return spring.

3. Remove the fuel rod end bearing or ball joint from the terminal shaft lever and the terminal lever from the terminal shaft.

4. Place the terminal lever on the terminal shaft so that the hole for attaching the fuel rod end bearing or ball joint is in line vertically above the terminal lever shaft at one half the arc of travel. Do not tighten the clamping bolt.

5. Hold the injector rack control tube and the terminal lever in the *full-fuel* position and adjust the length of the fuel rod until the end bearing or ball joint will slide freely into the hole of the terminal lever as shown in Fig. 3. Tighten the lock nut to retain the ball

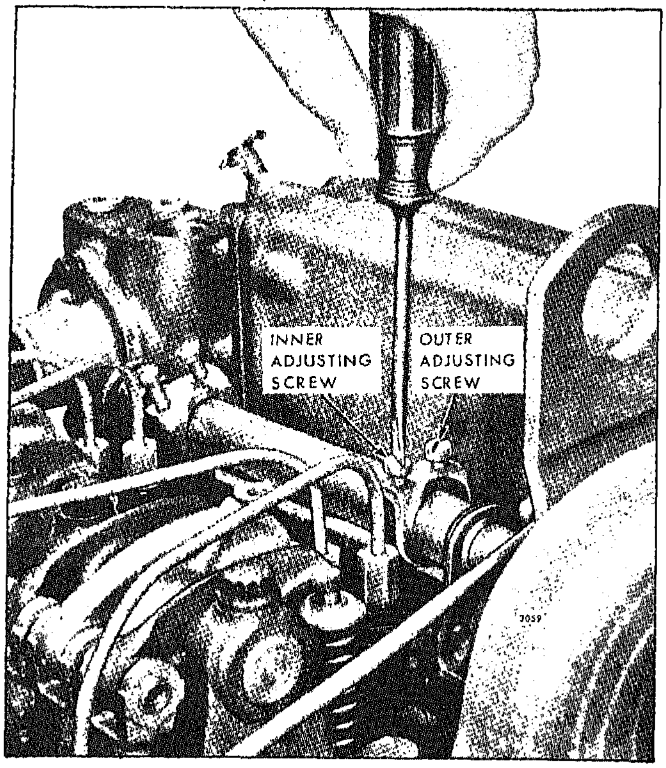


Fig. 2 - Adjusting Height of Rack Control Lever Adjusting Screws

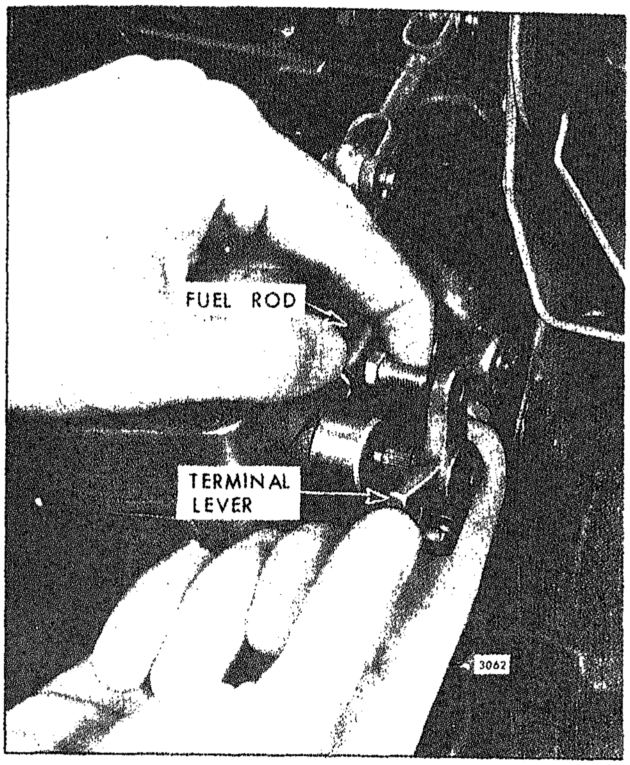


Fig. 3 - Adjusting Length of Fuel Rod

joint or end bearing and the terminal lever clamping bolt securely.

> **NOTE:** It will be necessary to slide the terminal lever partially off of the shaft to attach the fuel rod end bearing or ball joint to the terminal lever.

6. Hold the terminal lever in the *full-fuel* position and loosen the inner adjusting screw 1/8 of a turn and tighten the outer adjusting screw 1/8 of a turn to retain the adjustment. This is done to prevent the governor from bottoming the injector racks, since there is no load limit screw on this governor.

7. Remove the clevis pin between the fuel rod and the injector control tube lever.

> **NOTE:** Cover the cylinder head oil drain back hole, located under the control lever, when removing the fuel rod clevis pin to prevent its loss and possible damage to the engine.

8. Manually hold the rear injector in the *full-fuel* position and turn down the inner rack control lever adjusting screw of the adjacent injector until the injector rack of the adjacent injector has moved into the *full-fuel* position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer rack control lever adjusting screws.

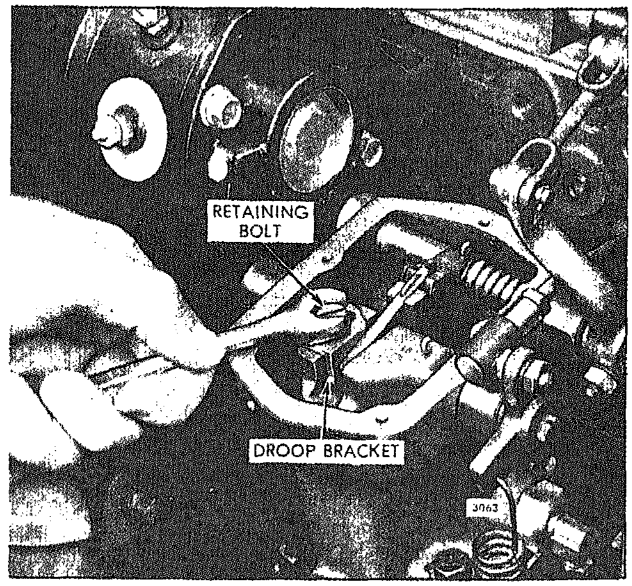


Fig. 4 - Adjusting Droop Bracket

9. Recheck the rear injector fuel rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off slightly on the inner adjusting screw on the adjacent injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

10. Position the remaining rack control levers as outlined in Steps 8 and 9.

11. Insert the clevis pin between the fuel rod and the injector control tube lever.

12. Install the terminal lever return spring.

Adjust Speed Droop

The purpose of adjusting the speed droop is to establish a definite engine speed at no load with a given speed at rated full load.

The governor droop is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs, the speed droop should be readjusted.

The best method of determining the engine speed is with an accurate hand tachometer.

Full Load	No-Load
50 cycles 1000 rpm	52.5 cycles 1050 rpm
60 cycles 1200 rpm	62.5 cycles 1250 rpm
50 cycles 1500 rpm	52.5 cycles 1575 rpm
60 cycles 1800 rpm	62.5 cycles 1875 rpm

TABLE 1

If a full-rated load can be established on the engine and the fuel rod, injector rack control levers and load limit have been adjusted, the speed droop may be adjusted as follows:

1. Start the engine and run it at approximately one-half the rated no-load speed until the lubricating oil temperature stabilizes.

NOTE: When the engine lubricating oil is cold, the governor regulation may be erratic. The regulation should become increasingly stable as the temperature of the lubricating oil increases.

2. Stop the engine and remove the governor cover. Discard the gasket.

3. Loosen the lock nut and back off the maximum speed adjusting screw (Fig. 5) approximately 5/8″

4. Refer to Fig. 4 and loosen the droop adjusting bolt. Move the droop bracket so that the bolt is midway between the ends of the slot in the bracket. Tighten the bolt.

5. With the throttle in the *run* position, adjust the engine speed until the engine is operating at 3% to 5% above the recommended full-load speed.

6. Apply the full-rated load on the engine and re-adjust the engine speed to the correct full-load speed.

7. Remove the rated load and note the engine speed after the speed stabilizes under no-load. If the speed droop is correct, the engine speed will be approximately 3% to 5% higher than the full-load speed.

If the speed droop is too high, stop the engine and again loosen the droop bracket retaining bolt and move the droop adjusting bracket *in* toward the engine. Tighten the bolt. To increase the speed droop, move the droop adjusting bracket *out,* away from the engine.

The speed droop in governors which control engines driving generators in parallel must be identical, otherwise, the electrical load will not be equally divided.

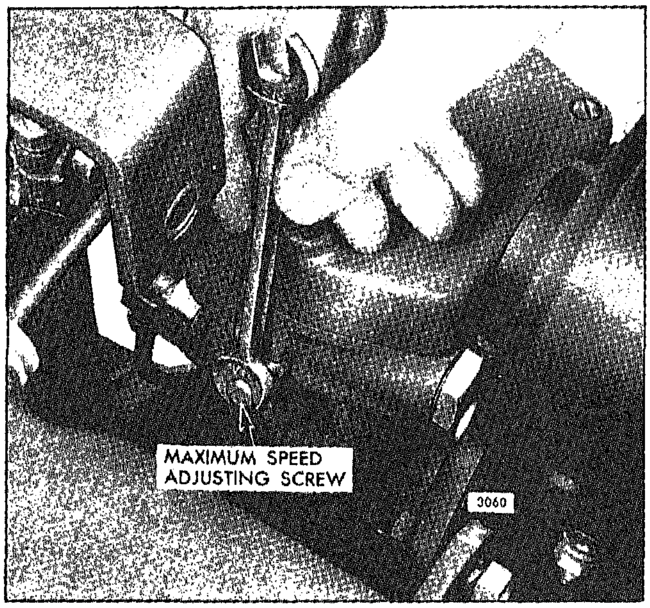


Fig. 5 - Adjusting Maximum Engine Speed

Adjust the speed droop bracket in each engine governor to obtain the desired variation between the engine no-load and full-load speeds shown in Table 1.

The recommended speed droop of generator sets operating in parallel is 50 rpm (2-1/2 cycles) for units operating at 1000 and 1200 rpm and 75 rpm (2-1/2 cycles) for units operating at 1500 rpm and 1800 rpm full load. This speed droop recommendation may be varied to suit the individual application.

Adjust Maximum No-Load Speed

With the speed droop properly adjusted, set the maximum no-load speed as follows:

1. Loosen the maximum speed adjusting screw lock nut and back out the maximum speed adjusting screw three turns.

2. With the engine operating at no-load, adjust the engine speed until the engine is operating at approximately 8% higher than the rated full-load speed.

3. Turn the maximum speed adjusting screw (Fig. 5) in lightly until contact is felt with the linkage in the governor.

4. Hold the maximum speed adjusting screw and tighten the lock nut.

5. Use a new gasket and install the governor cover.

HYDRAULIC GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

6V-53 ENGINE

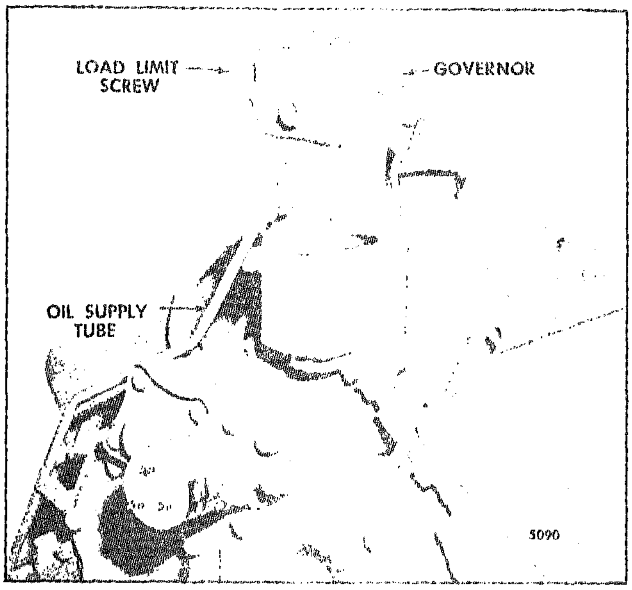


Fig. 1 · Hydraulic Governor Mounting

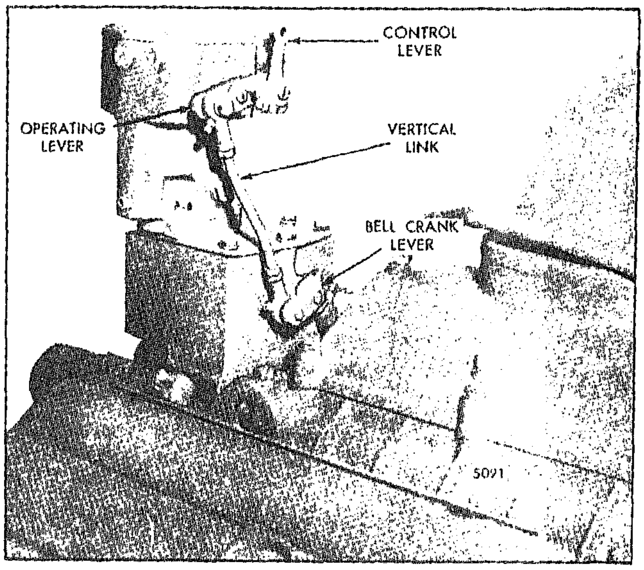


Fig. 2 · Hydraulic Governor Controls

The hydraulic governor is mounted between the blower and the rear end plate as shown in Fig. 1. The vertical control link assembly is attached to the governor operating lever and the bell crank lever on the governor drive housing (Fig. 2).

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor as follows:

1. Disconnect the vertical control link assembly from the governor operating lever.

2. Loosen all of the injector rack control lever adjusting screws.

3. While holding the bell crank lever (on the governor drive housing) in a horizontal position (full-fuel), set the No. 3 injector rack control levers on each bank to full-fuel.

4. Position the remaining rack control levers to the No. 3 control levers.

5. Remove the governor cover. Discard the gasket.

6. To determine the full-fuel position of the terminal lever, adjust the load limit screw to obtain a distance of 2″ from the outside face of the boss on the governor sub-cap to the end of the screw.

7. Adjust the operating lever (on the governor) so that it is horizontal, or slightly below (as close as the serrations on the shaft will permit) when the shaft is rotated to the full-fuel position, or clockwise when viewed from the front of the engine.

8. Loosen the lock nut and adjust the length of the vertical link assembly, attached to the bell crank lever, to match the full-fuel position of the governor operating lever and the injector rack control levers. This length should be approximately 6-5/16″ Tighten the lock nut.

9. With the governor operating lever held in the *full-fuel* position, turn the load limit screw ((Fig. 1) inward until the injector racks just loosen on the ball end of the control levers, to prevent the injector racks from bottoming.

10. Release the governor operating lever and hold the adjusting screw while tightening the lock nut.

11. Use new gaskets and install the governor cover and the valve rocker covers.

TROUBLE SHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.

2. The injector of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty fuel injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.

2. Stop the engine and remove the valve rocker cover(s). Discard the gasket(s).

3. Check the valve clearance. The clearance should be .009" (two valve cylinder head) or .024" (four valve cylinder head).

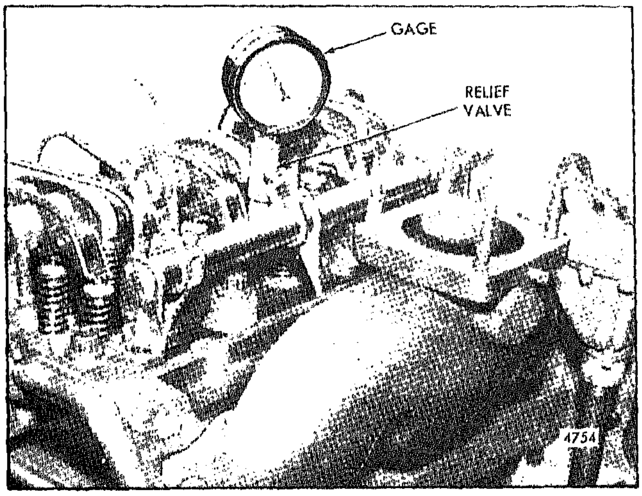


Fig. 1 · Checking Compression Pressure

4. Start the engine and hold an injector follower down with a screw driver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

6. If the cylinder is misfiring, check the following:

a. Check the injector timing (refer to *Engine Tune-Up Procedure).*

b. Check the compression pressure.

c. Install a new injector.

d. If the cylinder still misfires, remove the cam follower and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

7. If installation of a new injector does not eliminate misfiring, check the compression pressure.

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

Minimum Compression Pressure, psi		Altitude, Feet Above Sea Level
Std. Engine	"N" Engine	
430	540	0
400	500	2,500
370	465	5,000
340	430	7,500
315	395	10,000

TABLE 1

2. Stop the engine and remove the fuel pipes from the No. 1 injector and the fuel connectors.

3. Remove the injector and install adaptor J 7915-02 and pressure gage and hose assembly J 6992 (Fig. 1).

4. Use a spare fuel pipe and fabricate a jumper connection between the fuel inlet and return fuel connectors to permit fuel to flow directly to the fuel return manifold.

5. Start the engine and run it at 600 rpm. Observe and record the compression pressure indicated on the gage.

NOTE: Do not crank the engine with the starting motor to check the compression pressure.

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder should not be less than 430 psi (540 psi for "N" engines) at 600 rpm. In addition, the variation in compression pressures between cylinders of the engine must not exceed 25 psi at 600 rpm.

EXAMPLE: If the compression pressure readings were as shown in Table 2, it would be evident that No. 3 cylinder should be examined and the cause of the low compression pressure be determined and corrected.

Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 3 cylinder compression pressure indicates that something unusual has occurred and that a localized pressure leak has developed.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and press on the compression rings with a blunt tool. A broken or stuck compression ring will not have a "spring-like" action.

B. Compression pressure may be leaking past the cylinder head gasket, valve seats, injector tubes or through a hole in the piston.

Cylinder	Gage Reading*
1	525 psi (3617 kPa)
2	520 psi (3583 kPa)
3	485 psi (3342 kPa)
4	515 psi (3548 kPa)

*The above pressures are for an engine operating at an altitude near sea level.

TABLE 2

Engine Out of Fuel

The problem in restarting the engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it. The procedure is outlined below:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons of fuel.

2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

NOTE: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut in order to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the engine fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

1. Disconnect the fuel return hose from the fitting at the fuel tank and hold the open end in a suitable container.

2. Start and run the engine at 1200 rpm and measure the fuel flow for a period of one minute. At least .6 gallon of fuel should flow from the fuel return hose per minute.

3. Immerse the end of the fuel return hose in the fuel in the container. Air bubbles rising to the surface of the

CRANKCASE PRESSURE (max. in inches of water)					
Engine	Speed (rpm)				
	1800	2000	2200	2500*	2800*
3-53	.5	.5	.5	.9	1.0
4-53	.5	.5	.5	.9	1.0
4-53T	—	—	—	1.0	—
6V-53	—	—	—	.9	1.0

*Engines with four valve cylinder head(s).

TABLE 3

EXHAUST BACK PRESSURE (max. in inches of Mercury)					
Engine	No-Load Speed (rpm)				
	1800	2000	2200	2500*	2800*
3-53	1.3	1.7	2.1	2.7	2.7†
4-53	1.3	1.7	2.1	2.7	2.7†
4-53T	—	—	—	1.8	—
6V-53	—	—	—	2.7	2.7†

*Engines with four valve cylinder head(s).
†3.8 for Marine engines.

TABLE 4

fuel will indicate air being drawn into the fuel system on the suction side of the pump.

If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.

If the fuel flow fails to meet the amount specified, the fuel strainer, filter or pump should be serviced.

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liner into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head or end plate gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

The crankcase pressure may be checked with a manometer connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the specifications in Table 3.

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss in the efficiency of the blower. This means less air for

AIR BOX PRESSURE (min. in inches of Mercury)					
Max. Exhaust Back Pressure (Full Load)					
Engine	Speed (rpm)				
	1800	2000	2200	2500*	2800*
3-53	5.5	6.9	8.6	8.0	9.3
4-53	5.5	6.9	8.6	8.0	9.3
4-53T	—	—	—	33.5	—
6V-53	—	—	—	8.0	9.3
(Zero Exhaust Back Pressure)					
3-53	3.8	4.9	6.2	4.8	6.1
4-53	3.8	4.9	6.2	4.8	6.1
4-53T	—	—	—	31.5	—
6V-53	—	—	—	4.8	6.1

*Engines with four valve cylinder head(s).

TABLE 5

scavenging, which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

The exhaust back pressure, measured in inches of mercury, may be checked with a manometer, or pressure gage, connected to the exhaust manifold. Remove the 1/8" pipe plug, which is provided for that purpose, from the manifold. If there is no opening provided, one can be made by drilling an 11/32" hole

AIR INLET RESTRICTION (inches of water)					
Engine	Speed (rpm)				
	1800	2000	2200	2500*	2800*
Max. with dirty air cleaner (oil bath or dry)					
3-53	13.4	—	18.8	23.0	25.0
4-53	13.4	—	18.8	23.0	25.0
6V-53	—	—	18.8	23.0	25.0
Max. with clean air cleaner (oil bath)					
3-53	9.5	10.8	12.0	14.0	16.0
4-53	9.5	10.8	12.0	14.0	16.0
6V-53	—	—	12.0	14.0	16.0
Max. with clean air cleaner (Dry with precleaner)					
3-53	6.8	10.8	12.0	—	—
4-53	6.8	10.8	12.0	—	—
Max. with clean air cleaner (Dry less precleaner)					
3-53	5.5	6.5	7.4	8.7	10.0
4-53	5.5	6.5	7.4	8.7	10.0
6V-53	—	—	7.4	8.7	10.0
Max. with air silencer (full load)					
4-53T	—	—	—	20.0	—

*Engines with four valve cylinder heads.

TABLE 6

in the exhaust manifold companion flange and tapping a 1/8" pipe thread.

Check the readings obtained at various speeds (no load) with the specifications in Table 4.

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as a leaking end plate gasket), or a clogged blower air inlet screen.

Lack of power or black or grey exhaust smoke are indications of low air box pressure.

To check the air box pressure, connect a manometer to an air box drain tube.

Check the readings obtained at various speeds with the specifications in Table 5.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently, the restriction must be kept to a minimum considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

The air inlet restriction may be checked with a manometer connected to a fitting in the air intake ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air intake vacuum at various speeds (at no-load) and compare the results with Table 6.

PROPER USE OF MANOMETER

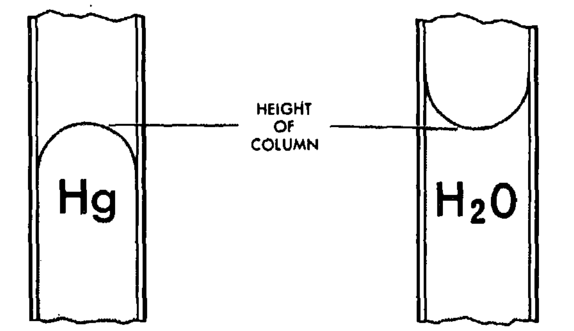


Fig. 2 - Comparison of Column Height for Mercury and Water Manometers

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

PRESSURE CONVERSION CHART		
1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	.4919 psi
1" mercury	=	13.6000" water
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury

TABLE 7

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a *convex* meniscus (shape). Water wets the surface and therefore has a *concave* meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 7 to convert manometer readings into other units of measurement.

ENGINE ELECTRICAL GENERATING SYSTEM

Whenever trouble is indicated in the engine electrical generating system, the following quick checks can be made to assist in localizing the cause.

A fully charged battery and low charging rate indicates normal alternator-regulator operation.

A low battery and high charging rate indicates normal alternator-regulator operation.

A fully charged battery and high charging rate condition usually indicates the voltage regulator is set too high or is not limiting the alternator output. A high charging rate to a fully charged battery will damage the battery and other electrical components.

A low battery and low or no charging rate condition could be caused by: Loose connections or damaged wiring, defective battery or alternator, or defective regulator or improper regulator setting.

Contact an authorized *Detroit Diesel Allison Service Outlet* if more information is needed.

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 days or less)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.

2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.

3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

   NOTE: Do not drain the fuel system or the crankcase after this run.

4. Check the air cleaner and service it, if necessary, as outlined under *Air System.*

5. If freezing weather is expected during the storage period, add a high boiling point type antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the drain cocks open.

6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with air.

7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission, and priming the raw water pump, if used.

EXTENDED STORAGE (30 days or more)

When an engine is to be removed from operation for an extended period of time, prepare it as follows:

1. Drain and thoroughly flush the cooling system with clean, soft water.

2. Refill the cooling system with clean, soft water.

3. Add a rust inhibitor to the cooling system (refer to *Corrosion Inhibitor* under *Cooling System).*

4. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.

5. Reinstall the injectors in the engine, time them, and adjust the valve clearance.

6. Circulate the coolant through the entire system by operating the engine until normal operating temperature is reached (160-185° F or 71-85° C).

7. Stop the engine.

8. Remove the drain plug and completely drain the engine crankcase. Reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.

9. Fill the crankcase to the proper level with a 30-weight preservative lubricating oil MIL-L-21260, Grade 2 (P10), or equivalent.

10. Drain the engine fuel tank.

11. Refill the fuel tank with enough rust preventive fuel oil such as American Oil Diesel Run-In Fuel (LF

4089), Mobil 4Y17, or equivalent, to enable the engine to operate 10 minutes.

12. Drain the fuel filter and strainer. Remove the retaining bolts, shells and elements. Discard the used elements and gaskets. Wash the shells in clean fuel oil and insert new elements. Fill the cavity between the element and shell about two-thirds full of the same rust preventive compound as used in the fuel tank and reinstall the shell.

13. Operate the engine for 10 minutes to circulate the rust preventive throughout the engine.

14. Refer to *Air System* and service the air cleaner.

15. MARINE GEAR

a. Drain the oil completely and refill with clean oil of the proper viscosity and grade as is recommended. Remove, clean or replace the strainer and replace the filter element.

b. Start and run the engine at 600 rpm for 5 minutes so that clean oil can coat all of the internal parts of the marine gear. Engage the clutches alternately to circulate clean oil through all of the moving parts.

16. TORQMATIC CONVERTER

a. Start the engine and operate it until the temperature of the converter oil reaches 150 °F (66 °C).

b. Remove the drain plug and drain the converter.

c. Remove the filter element.

d. Start the engine and stall the converter for twenty seconds at 1000 rpm to scavenge the oil from the converter. *Due to lack of lubrication, do not exceed the 20 second limit.*

e. Install the drain plug and a new filter element.

f. Fill the converter to the proper operating level with a commercial preservative oil which meets Government specifications MIL-L-21260, Grade 1. Oil of this type is available from the major oil companies.

g. Start the engine and operate the converter for at least 10 minutes at a minimum of 1000 rpm. Engage the clutch; then stall the converter to raise the oil temperature to 225 °F (107 °C).

CAUTION: Do not allow the oil temperature to exceed 225 °F (107 °C). If the unit does not have a temperature gage, *do not stall the converter for more than thirty seconds.*

h. Stop the engine and permit the converter to cool to a temperature suitable to touch.

i. Seal all of the exposed openings and the breather with moisture proof tape.

j. Coat all exposed, unpainted surfaces with preservative grease. Position all of the controls for minimum exposure and coat them with grease. The external shafts, flanges and seals should also be coated with grease.

17. POWER TAKE-OFF

a. With an all purpose grease such as Shell Alvania No. 2, or equivalent, lubricate the clutch throwout bearing, clutch pilot bearing, drive shaft main bearing, clutch release shaft, and the outboard bearings (if so equipped).

b. Remove the inspection hole cover on the clutch housing and lubricate the clutch release lever and link pins with a hand oiler. Avoid getting oil on the clutch facing.

c. If the unit is equipped with a reduction gear, drain and flush the gear box with light engine oil. If the unit is equipped with a filter, clean the shell and replace the filter element. Refill the gear box to the proper level with the oil grade indicated on the name plate.

18. TURBOCHARGER

The turbocharger bearings are lubricated by pressure through the external oil line leading from the engine cylinder block while performing the previous operations above and no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture-resistant tape.

19. HYDROSTARTER SYSTEM

Refer to *Hydraulic Starting System* in the section on *Engine Equipment* for the lubrication and preventive maintenance procedure.

20. Apply a *non-friction* rust preventive compound, to all exposed parts. If it is convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

CAUTION: Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat"

out during operation and cause the clutch to slip.

21. Drain the engine cooling system.

22. The oil may be drained from the engine crankcase if so desired. If the oil is drained, reinstall and tighten the drain plug.

23. Remove and clean the battery and battery cables with a baking soda solution and rinse them with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32° F.) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

24. Insert heavy paper strips between the pulleys and belts to prevent sticking.

25. Seal all of the openings in the engine, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

26. Clean and dry the exterior painted surfaces of the engine. Spray the surfaces with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

27. Cover the engine with a good weather-resistant tarpaulin or other cover if it must be stored outdoors. A clear plastic cover is recommended for indoor storage.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank, and electrical equipment. *Do not overlook the exhaust outlet.*

2. Wash the exterior of the engine with fuel oil to remove the rust preventive.

3. Remove the rust preventive from the flywheel.

4. Remove the paper strips from between the pulleys and the belts.

5. Remove the drain plug and drain the preservative oil from the crankcase. Re-install the drain plug. Then refer to *Lubrication System* in the *Operating Instructions* and fill the crankcase to the proper level with the recommended grade of lubricating oil.

6. Fill the fuel tank with the fuel specified under *Diesel Fuel Oil Specifications.*

7. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, add a high boiling point type antifreeze solution to the cooling system (the antifreeze contains a rust inhibitor).

8. Install and connect the battery.

9. Service the air cleaner as outlined under *Air System.*

10. POWER GENERATOR

Prepare the generator for starting as outlined under *Operating Instructions.*

11. MARINE GEAR

Check the Marine gear; refill it to the proper level, as necessary, with the correct grade of lubricating oil.

12. TORQMATIC CONVERTER

a. Remove the tape from the breather and all of the openings.

b. Remove all of the preservative grease with a suitable solvent.

c. Start the engine and operate the unit until the temperature reaches 150° F (66° C). Drain the preservative oil and remove the filter. Start the engine and stall the converter for twenty seconds at 1000 rpm to scavenge the oil from the converter.

CAUTION: A Torqmatic converter containing preservative oil should only be operated enough to bring the oil temperature up to 150° F (66° C).

d. Install the drain plug and a new filter element.

e. Refill the converter with the oil that is recommended under *Lubrication and Preventive Maintenance.*

13. POWER TAKE-OFF

Remove the inspection hole cover and inspect the clutch release lever and link pins and the bearing ends of the clutch release shaft. Apply engine oil sparingly, if necessary, to these areas.

14. HYDROSTARTER

a. Open the relief valve on the side of the hand pump and release the pressure in the system.

b. Refer to the filling and purging procedures outlined in *Hydraulic Starting System.* Then, drain, refill and purge the Hydrostarter system.

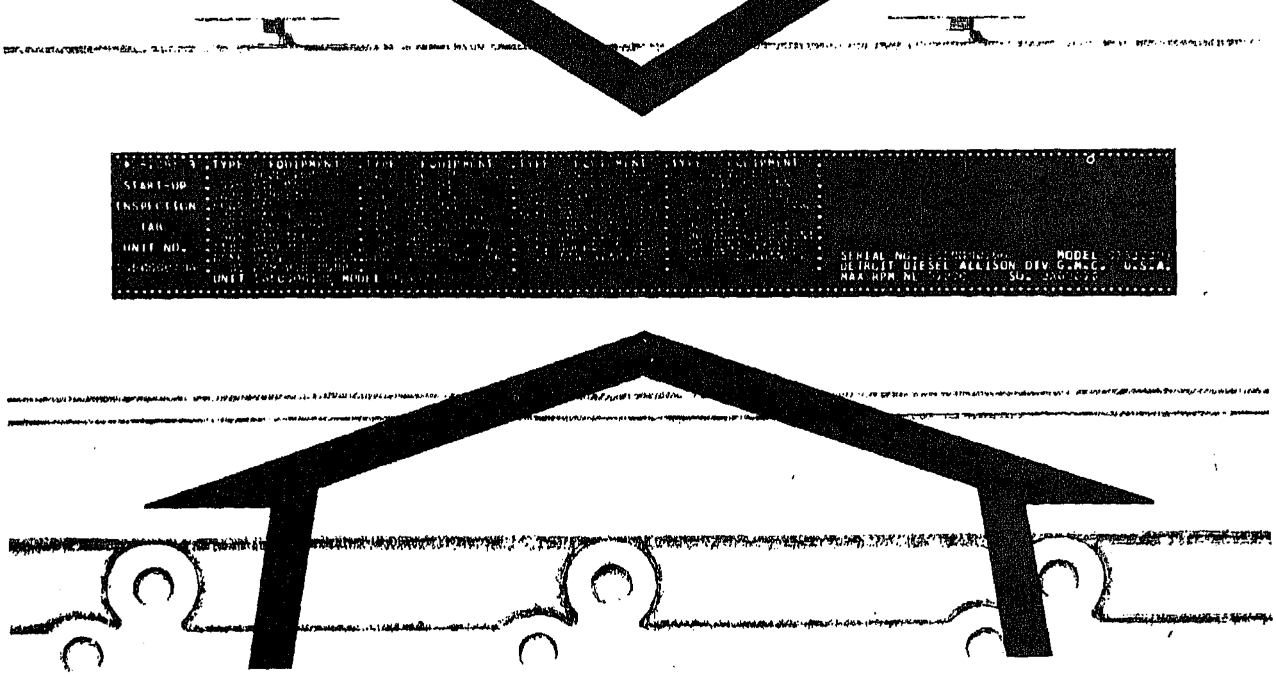
15. TURBOCHARGER

Remove the covers from the turbocharger air inlet and turbine outlet connections. Refer to the lubricating procedure outlined in *Preparation for Starting Engine First Time.*

16. After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause a smoky exhaust for a few minutes.

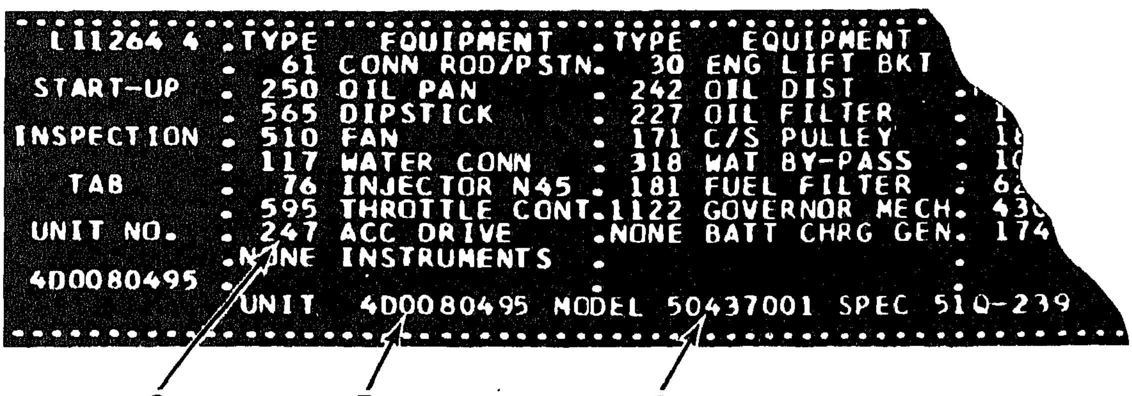
NOTE: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune-up.

BUILT-IN
PARTS BOOK
for
DETROIT DIESEL ENGINES



Progress in industry comes at a rapid pace. In order for the engine manufacturer to keep pace with progress he needs a versatile product for the many models and arrangements of accessories and mounting parts needed to suit a variety of equipment. In addition, engine refinements and improvements are constantly being introduced. All of this dynamic action must be documented so that the equipment can be serviced if and when it's needed. It is fully documented in the manufacturer's plant and in dealer Parts Departments with Master Files and adequate supporting records. But, what about YOU the user of this equipment? You have neither the time nor the inclination to ferret out specific part number data. What is the answer? – It is Detroit Diesel's exclusive BUILT-IN PARTS BOOK which is furnished with each engine. It takes the form of an "Option Plate" mounted on the rocker cover of the engine. With it, ordering parts becomes as simple as A, B, C. You have merely to provide the Dealer with . . .

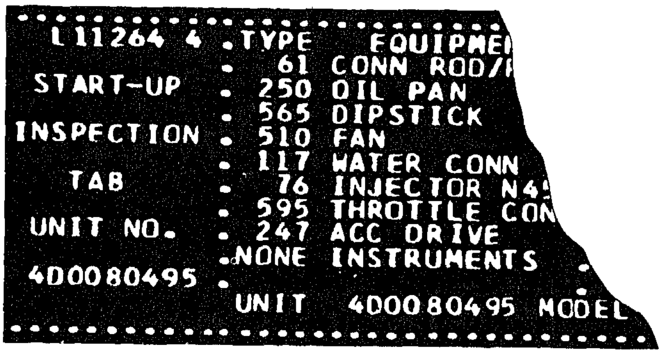
A. The "Model" number **B.** The "UNIT" number **C.** The "TYPE" number



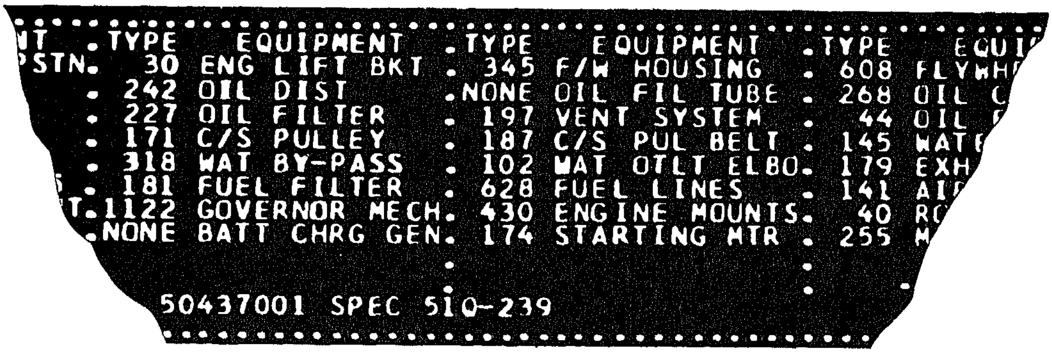
C. B. A.

From that much information, the dealer with his complete records on all engine models, can completely interpret your parts requirements.

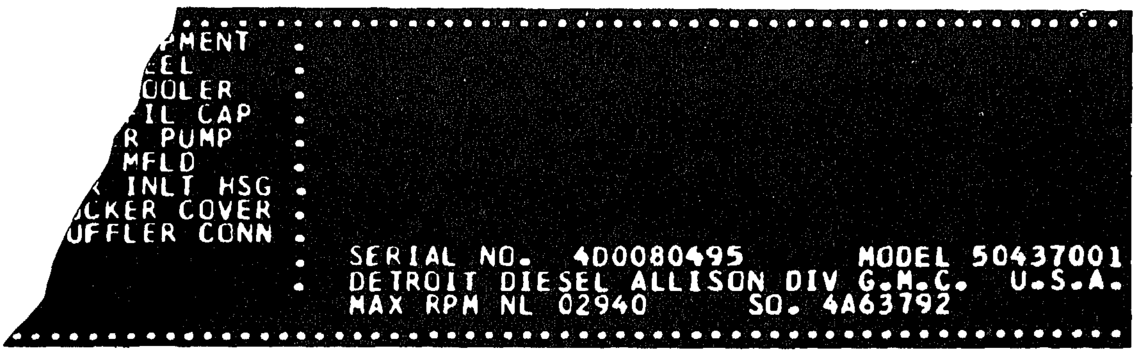
What is this "built-in" book? It is an anodized aluminum plate that fits into a holding channel on the engine rocker cover.



ON THE LEFT SIDE of the plate is the Start-up Inspection Tab which is removed by the dealer when he has completed the inspection.



NEXT is the type number and the equipment description. On the left is the type number. The type number designates all service parts applicable to the equipment. On the right is a brief description of the equipment.



ON THE RIGHT SIDE of the plate is pertinent data on the model number, serial number and the related governor setting.

All engine components are divided into groups of functionally related parts. A complete listing of the twelve major groups and their many sub-groups is shown below.

GROUP NOMENCLATURE

1.0000 ENGINE (less major assemblies)
- 1.1000 Cylinder Block
- 1.1000A Air Box Drains
- 1.2000 Cylinder Head
- 1.2000A Engine Lifter Bracket
- 1.3000 Crankshaft
- 1.3000A Crankshaft Front Cover
- 1.3000B Vibration Damper
- 1.3000C Crankshaft Pulley
- 1.3000D Crankshaft Pulley Belt
- 1.4000A Flywheel
- 1.5000A Flywheel Housing
- 1.5000B Flywheel Housing Adaptor
- 1.6000 Connecting Rod and Piston
- 1.7000 Camshaft and Gear Train
- 1.7000A Balance Weight Cover
- 1.7000B Accessory Drive
- 1.8000 Valve and Injector Operating Mechanism
- 1.8000A Rocker Cover

2.0000 FUEL SYSTEM
- 2.1000A Fuel Injector
- 2.2000 Fuel Pump
- 2.2000A Fuel Pump Drain
- 2.3000A Fuel Filter
- 2.4000 Fuel Manifold and/or Connections
- 2.5000A Fuel Lines
- 2.6000A Fuel Tank
- 2.7000A Mechanical Governor
- 2.8000A Hydraulic Governor
- 2.9000 Injector Controls
- 2.9000A Throttle Controls

3.0000 AIR SYSTEM
- 3.1000A Air Cleaner and/or Adaptor
- 3.2000A Air Silencer
- 3.3000A Air Inlet Housing
- 3.4000 Blower
- 3.4000A Blower Drive Shaft
- 3.5000A Turbocharger

4.0000 LUBRICATING SYSTEM
- 4.1000A Oil Pump
- 4.1000B Oil Distribution System
- 4.1000C Oil Pressure Regulator
- 4.2000A Oil Filter
- 4.3000A Oil Filter Lines
- 4.4000A Oil Cooler
- 4.5000A Oil Filler
- 4.6000A Dipstick
- 4.7000A Oil Pan
- 4.8000A Ventilating System

5.0000 COOLING SYSTEM
- 5.1000 Fresh Water Pump
- 5.1000A Fresh Water Pump Cover
- 5.2000A Water Outlet Manifold and/or Elbow
- 5.2000B Thermostat
- 5.2000C Water By-pass Tube
- 5.3000A Radiator
- 5.3000B Water Connections
- 5.4000A Fan
- 5.4000B Fan Shroud
- 5.5000A Heat Exchanger or Keel Cooling
- 5.6000A Raw Water Pump
- 5.7000A Water Filter

6.0000 EXHAUST SYSTEM
- 6.1000A Exhaust Manifold
- 6.2000A Exhaust Muffler and/or Connections

7.0000 ELECTRICAL-INSTRUMENTS
- 7.1000A Battery Charging Generator
- 7.2000B Automatic Starting
- 7.3000A Starting Motor
- 7.4000A Instruments
- 7.4000B Tachometer Drive
- 7.4000C Shut-off or Alarm System
- 7.5000A Power Generator
- 7.6000A Control Cabinet
- 7.7000A Wiring Harness
- 7.8000A Air Heater

8.0000 POWER TAKE-OFF
- 8.1000A Power Take-off and/or Clutch
- 8.3000A Torque Converter
- 8.3000B Torque Converter Lines

9.0000 TRANSMISSION AND PROPULSION
- 9.1000A Hydraulic Marine Gear
- 9.3000A Power Transfer Gear
- 9.4000 Transmission-Highway
- 9.7000 Transmission-Off-highway

10.0000 SHEET METAL
- 10.1000A Engine Hood

11.0000 ENGINE MOUNTING
- 11.1000A Engine Mounting and Base

12.0000 MISCELLANEOUS
- 12.2000A Bilge Pump
- 12.3000A Vacuum Pump
- 12.4000A Air Compressor
- 12.5000A Hydraulic Pump
- 12.6000A Gasoline Starter
- 12.6000B Air Starter
- 12.6000C Cold Weather Starting Aid
- 12.6000D Hydraulic Starter
- 12.6000E Hydraulic Starter Accessories

Within each of these sub-groups, various designs of similar equipment are categorized as "Types" and identified by a Type Number.

The Distributor/Dealer has a Model Index for each engine model. The Model Index lists all of the "Standard" and "Standard Option" equipment for that model.

DETROIT DIESEL 53 **5063-5000 (RA)**

STANDARD AND STANDARD OPTION EQUIPMENT

GROUP NAME	GROUP NO.	TYPE
Cylinder Block	1.1000	31
Air Box Drains	1.1000A	62
Cylinder Head (4 valve)	1.2000	26
Engine Lifter Bracket	1.2000A	44
Crankshaft	1.3000	44
Crankshaft Front Cover	1.3000A	65
Crankshaft Pulley (2 grooves)	1.3000C	171
Crankshaft Pulley Belt	1.3000D	121
Flywheel (SAE #3)	1.4000A	313
Flywheel Housing (SAE #3)	1.5000A	350
Connecting Rod and Piston	1.6000	68
Camshaft and Gear Train	1.7000	127
Valve Operating Mechanism	1.8000	33
Rocker Cover (with oil filler in one cover)	1.8000A	64
Fuel Injector *N50*	2.1000A	74
Fuel Pump (3/8" inlet) (mounted on L. Bank camshaft)	2.2000	73
Fuel Filter	2.3000A	358
Fuel Manifold Connections	2.4000	48
Fuel Lines	2.5000A	786
Governor - Mechanical	2.7000A	514

NOTE The option plate reflects which choice of options has been built into the engine. The Distributor/Dealer uses his model index to interpret the standard equipment. The plate, therefore, lists only the non-standard or choice items.

So, give the dealer the

A—Model No. __________
B—Unit No. __________
***C—Type No.** __________

*(If not shown, indicate "NONE". The dealer knows the "standard" for the model).

FOR READY REFERENCE, Record the information on the Option Plate to this record.

MODEL NO.____________________ **UNIT NO.**____________________

EQUIPMENT	TYPE	EQUIPMENT	TYPE	EQUIPMENT	TYPE
Engine Base		Water Bypass Tube		Battery Chrg. Generator	
Engine Lifter Brkt.		Thermostat		Starter	
Flywheel Housing		Water Filter		Hyd. Starter Acces.	
Vibration Damper		Exhaust Manifold		Starting Aid	
Flywheel		Air Cleaner or Silencer		Marine Gear	
Flywheel Hsg. Adptr.		Fuel Pump		Torque Converter	
Oil Pan		Injector		Torque Converter Lines	
Oil Pump		Blower		Muffler & Conn.	
Oil Distribution		Blower Drive Shaft		Engine Hood	
Dipstick		Fuel Filter		Wiring Harness	
Oil Pan Drain Tube		Fuel Lines		Instruments	
Oil Filler Tube or Cap		Air Inlet Housing		Tach. Drive	
Oil Cooler		Alarm or Shutoff		Radiator	
Oil Filter		Overspeed Governor		Heat Ex. or Keel Cooling	
Oil Lines		Throttle Controls		Raw Water Pump	
Ventilating System		Injector Controls		Power Generator	
Crankshaft Cover		Governor Mech or Hyd		Control Cabinet	
Balance Wgt. Cover		Engine Mounts		Cylinder Head	
Fan		Power Take-off		Conn Rod & Piston	
Crankshaft Pulley		Hydraulic Pump		Valve Mechanism	
Crankshaft Pulley Belt		Air Compressor		Fuel Manifold Conn	
Fan Shroud		Camshaft & Gear Train			
Water Connections		Rocker Cover			
Water Pump Cover		Accessory Drive			
Water Manifold					

OTHER USEFUL INFORMATION:

Each fuel and lube oil filter on your engine has a decal giving the service package part number for the element. It is advisable to have your own personal record of these part numbers by filling in the chart provided below:

TYPE	LOCATION	PACKAGE PART NO.
Fuel Strainer		
Fuel Filter		
Lube Oil Filter Full-Flo		
Lube Oil Filter By-Pass*		

*Not Standard

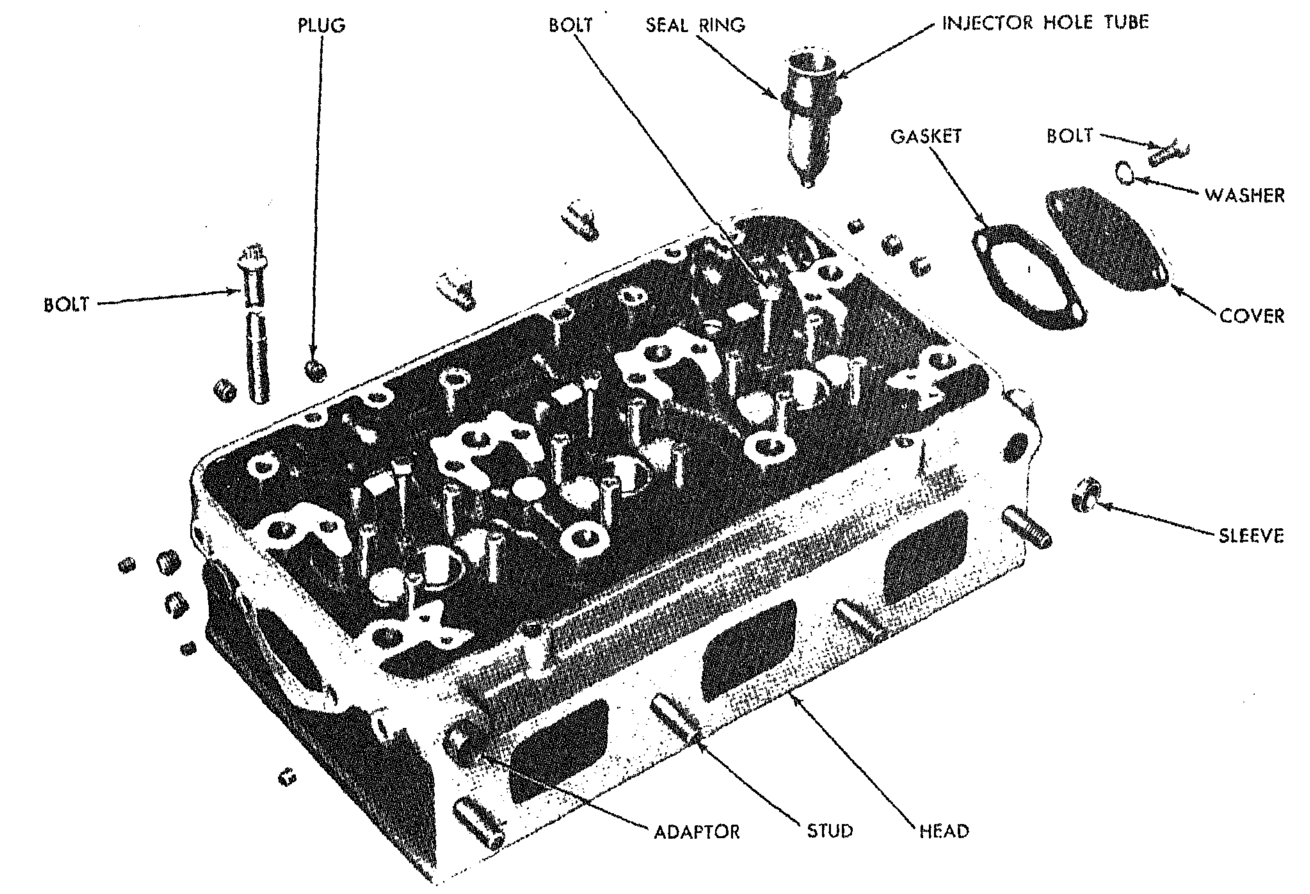
AIR CLEANER

If dry-type, indicate make and number of filter element:

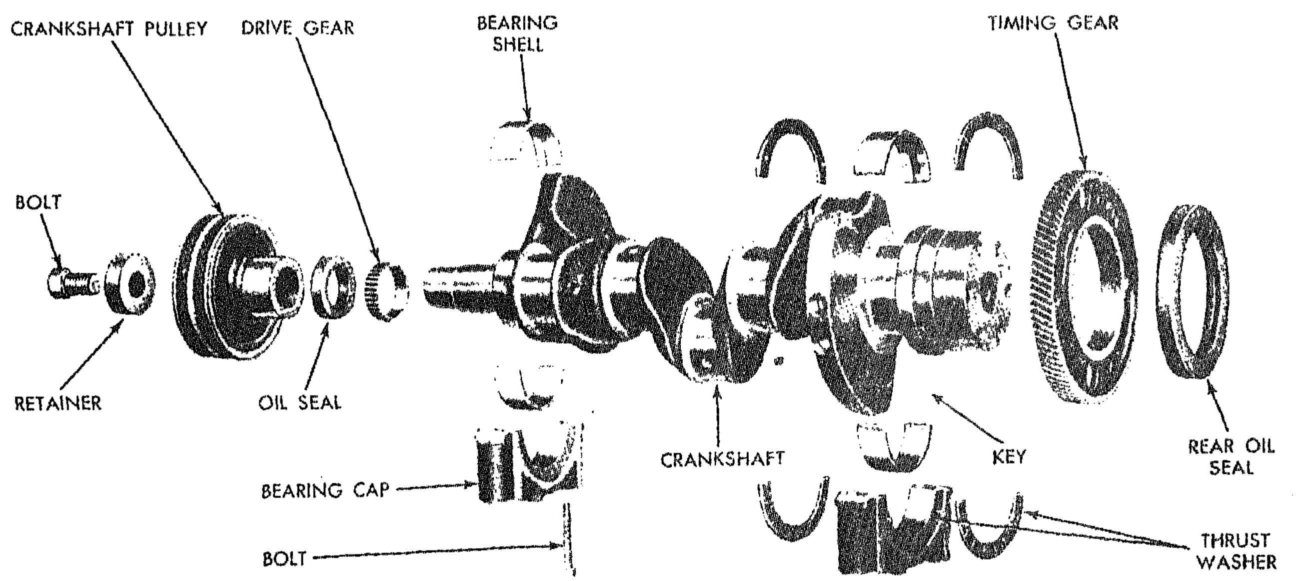
____

____

Wet type, indicate capacity__________qts.

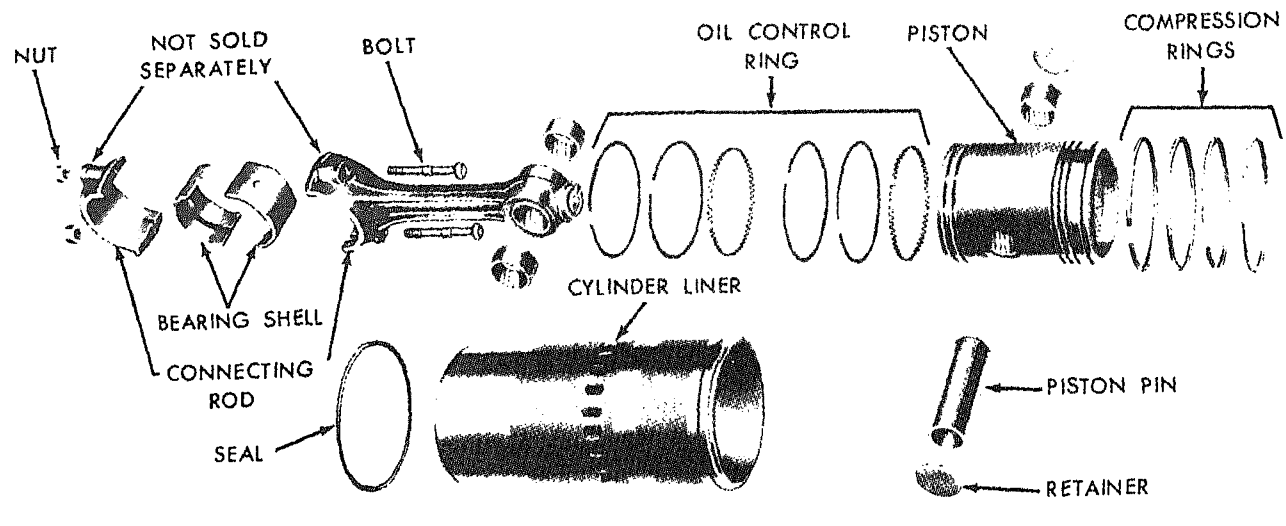


CYLINDER HEAD

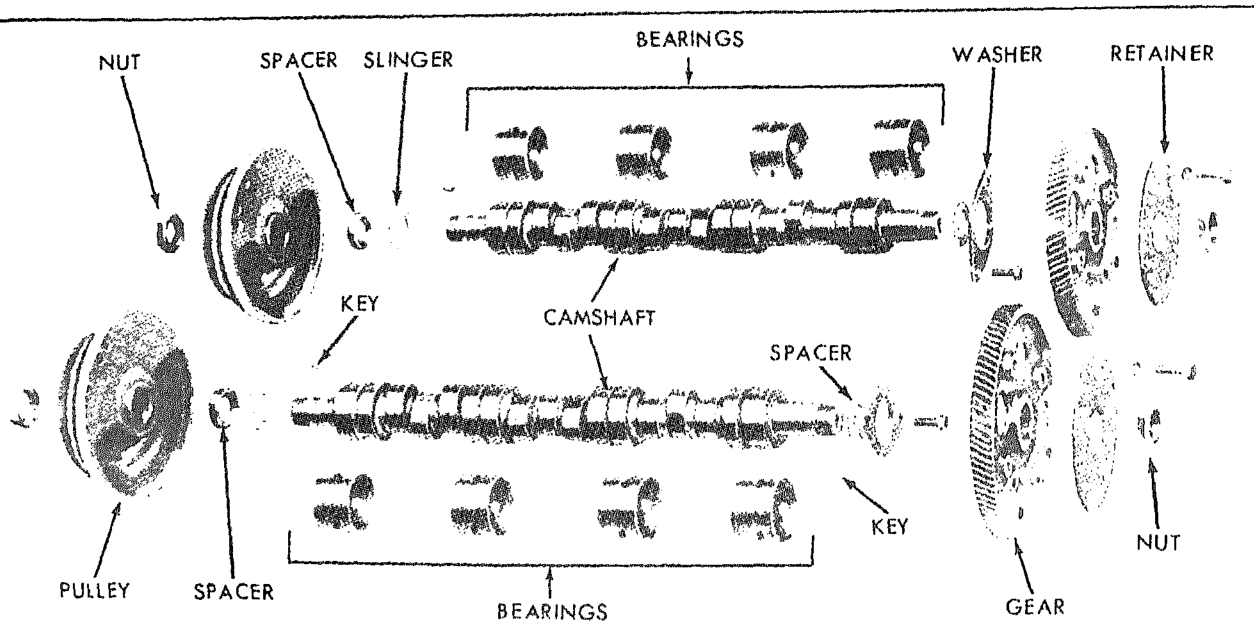


CRANKSHAFT

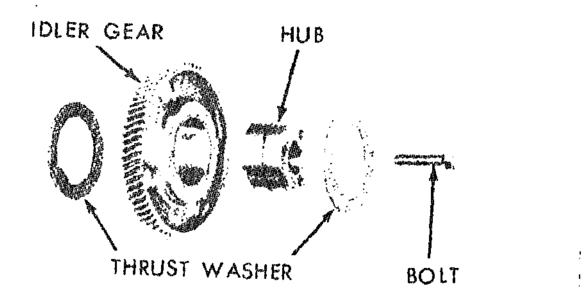
P 628



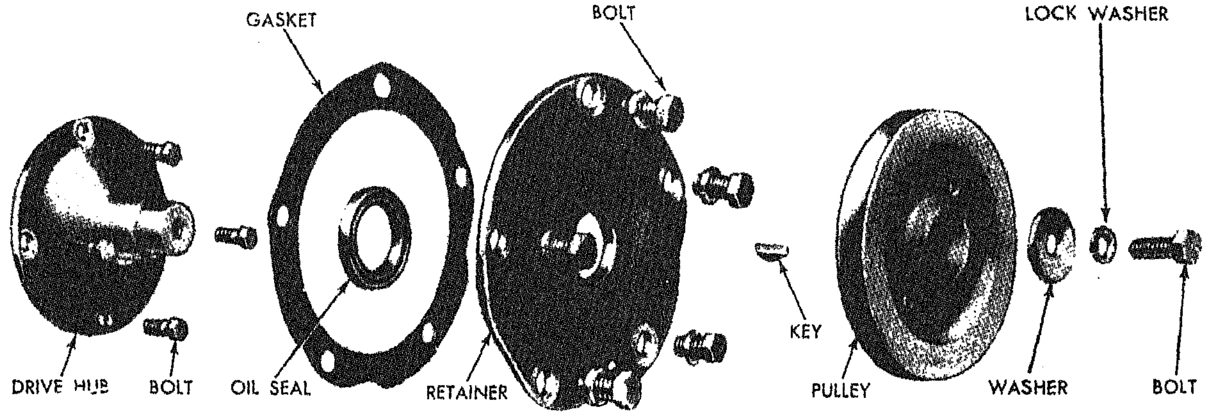
CONNECTING ROD, PISTON AND LINER



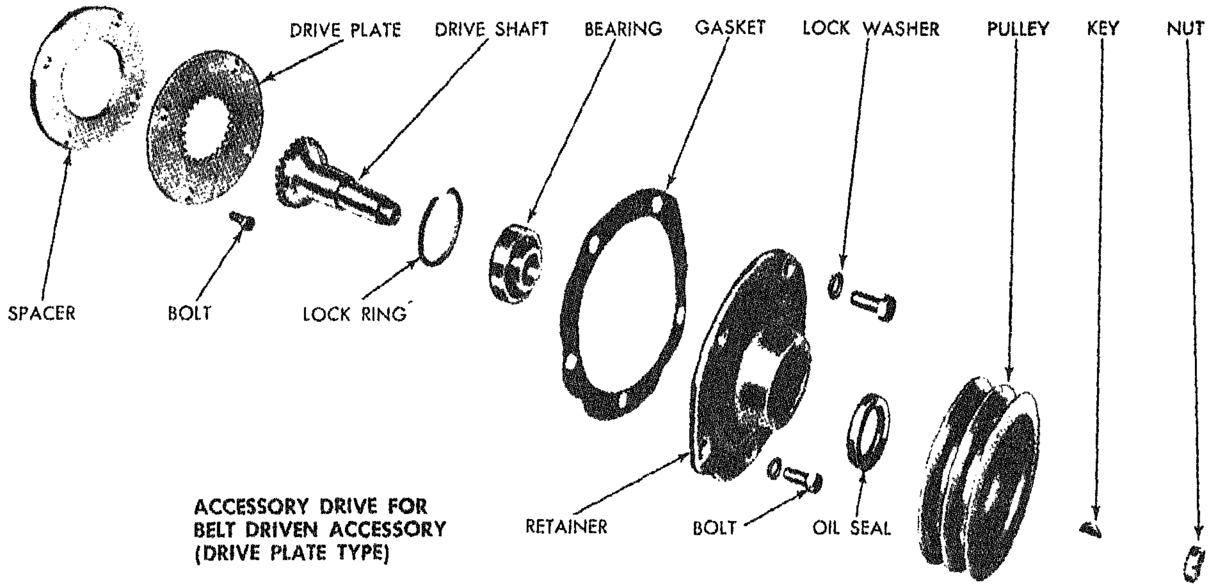
CAMSHAFT AND GEAR (V-ENGINE)



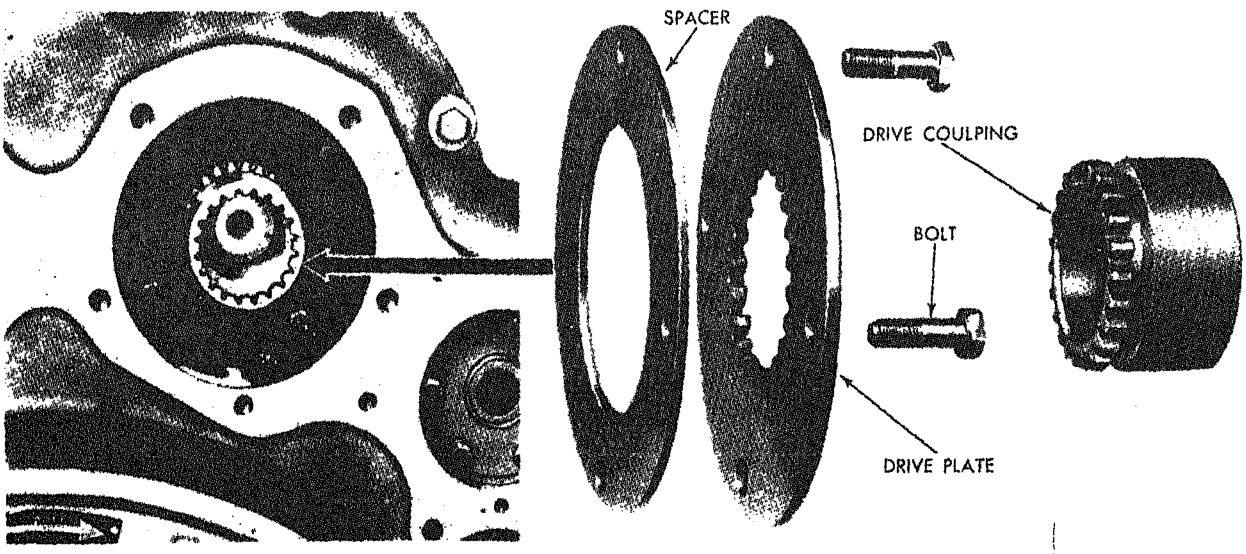
IDLER GEAR



ACCESSORY DRIVE FOR BELT DRIVEN ACCESSORY (DRIVE HUB TYPE)



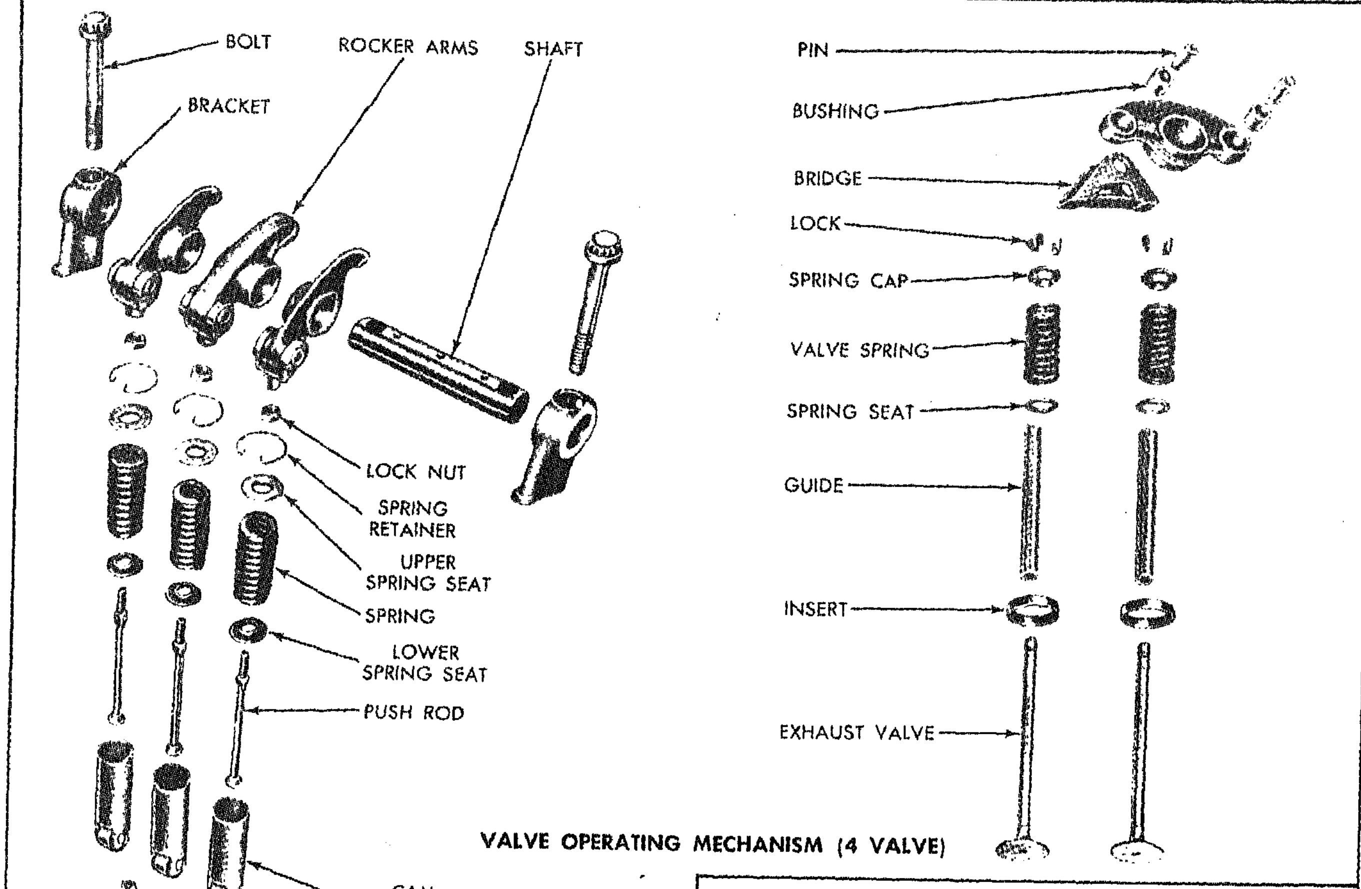
ACCESSORY DRIVE FOR BELT DRIVEN ACCESSORY (DRIVE PLATE TYPE)



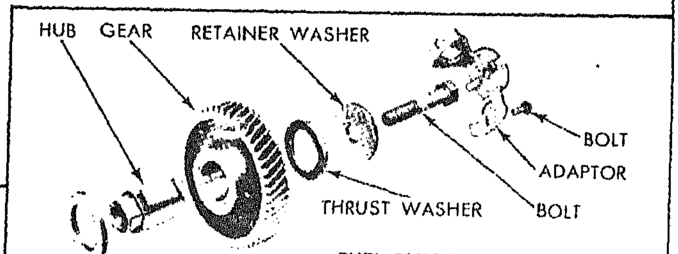
ACCESSORY DRIVE FOR DIRECT DRIVEN ACCESSORY (CAMSHAFT GEAR)

P 630

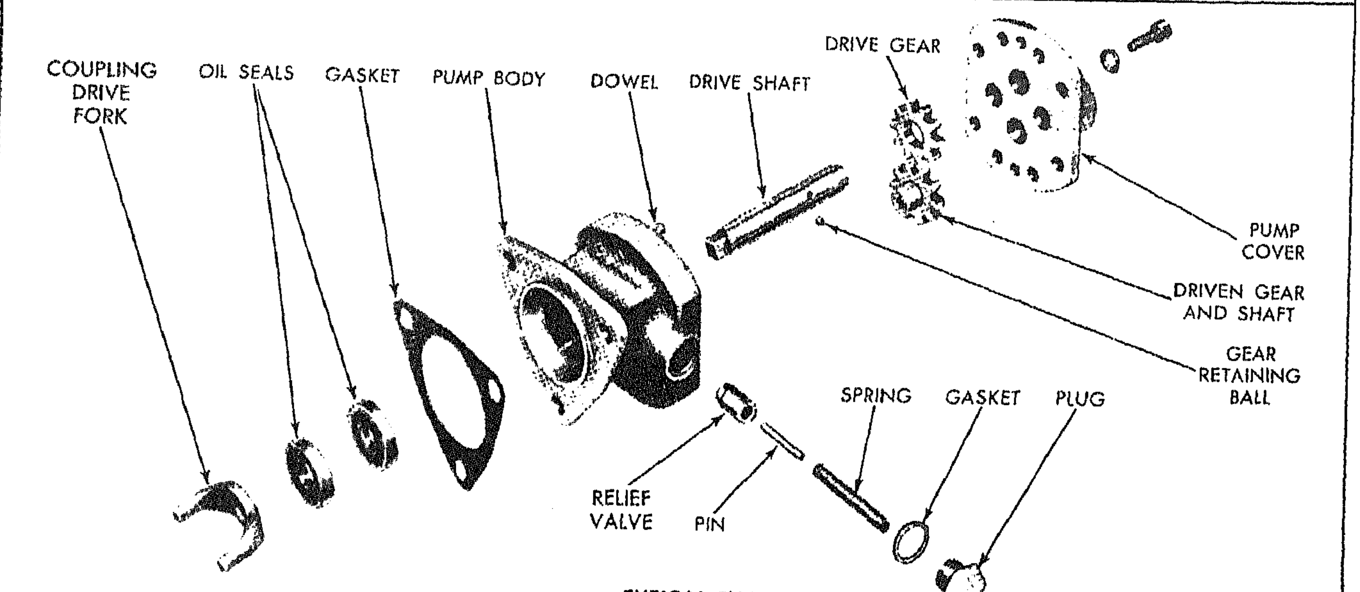
[redacted]



VALVE OPERATING MECHANISM (4 VALVE)

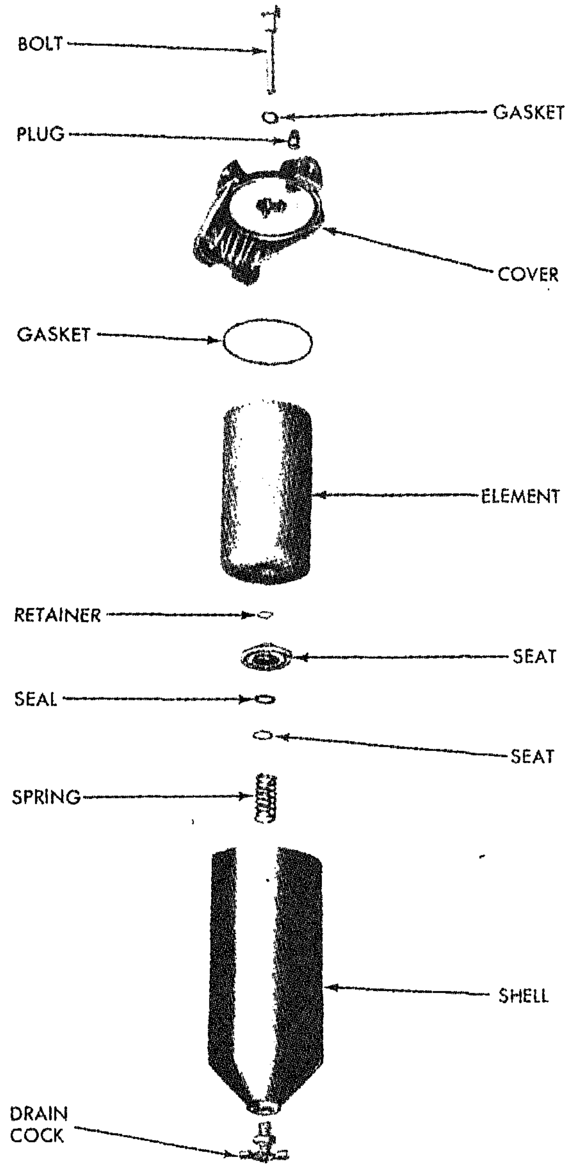


FUEL PUMP DRIVE (6V53)

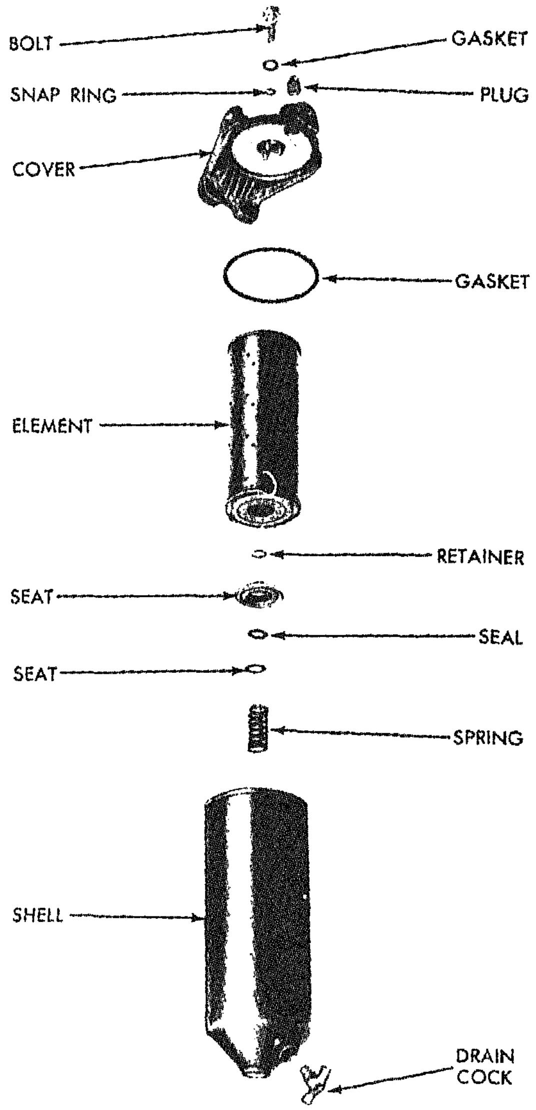


TYPICAL FUEL PUMP

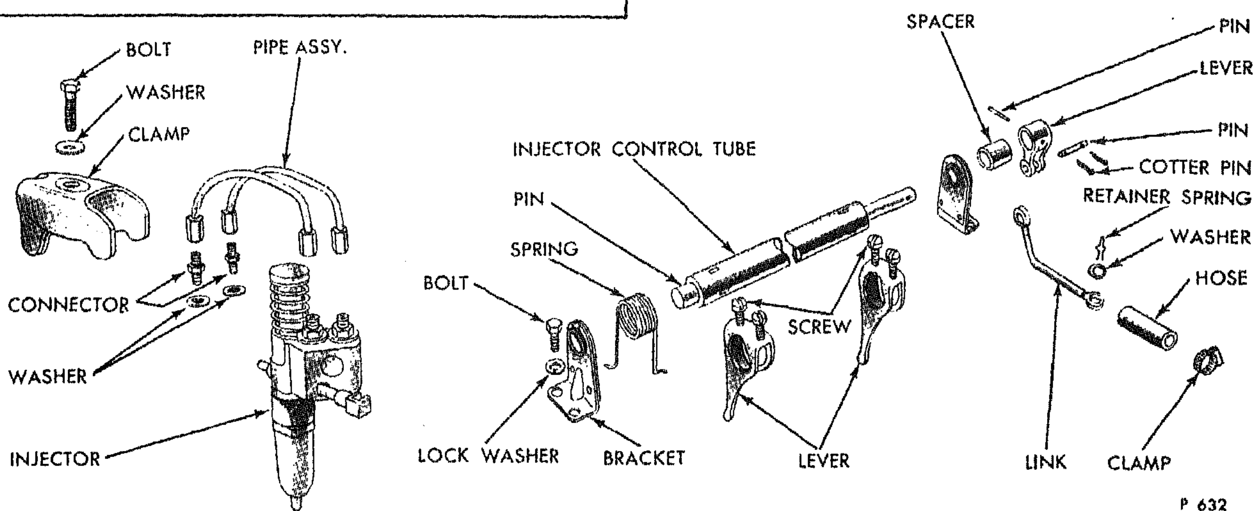
P 631



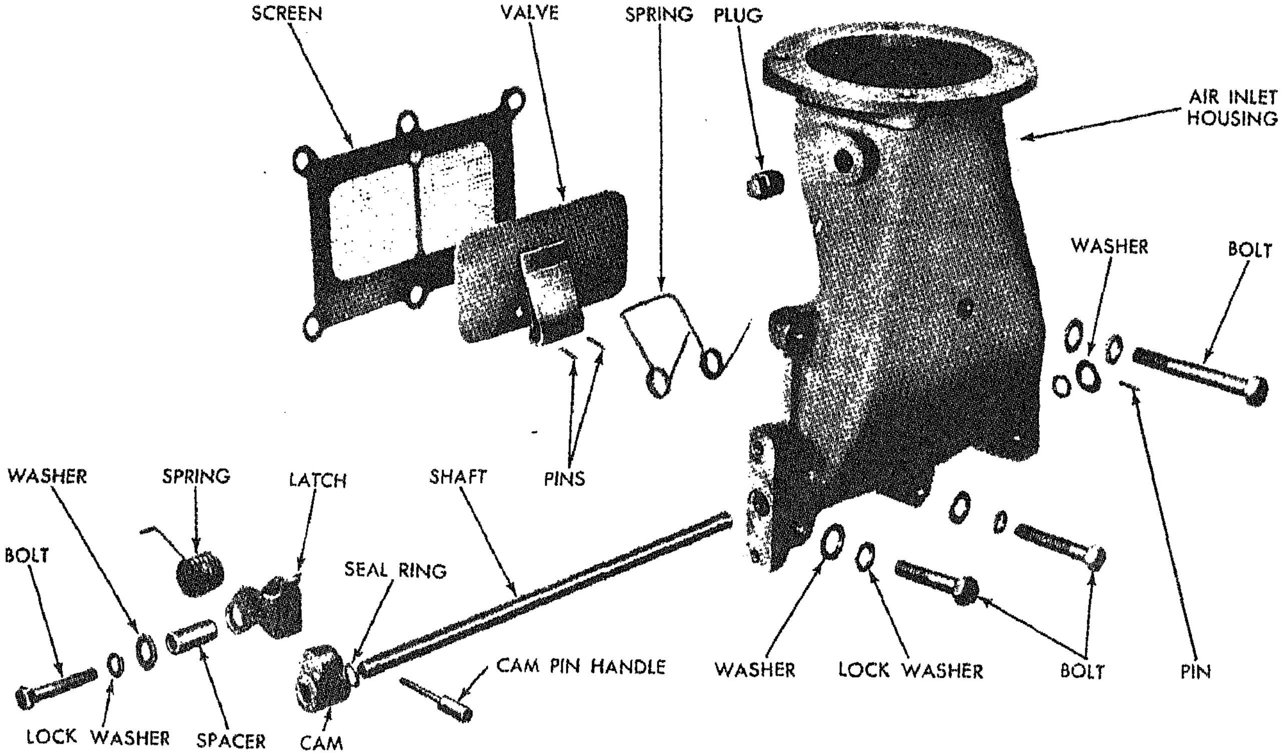
TYPICAL FUEL OIL STRAINER



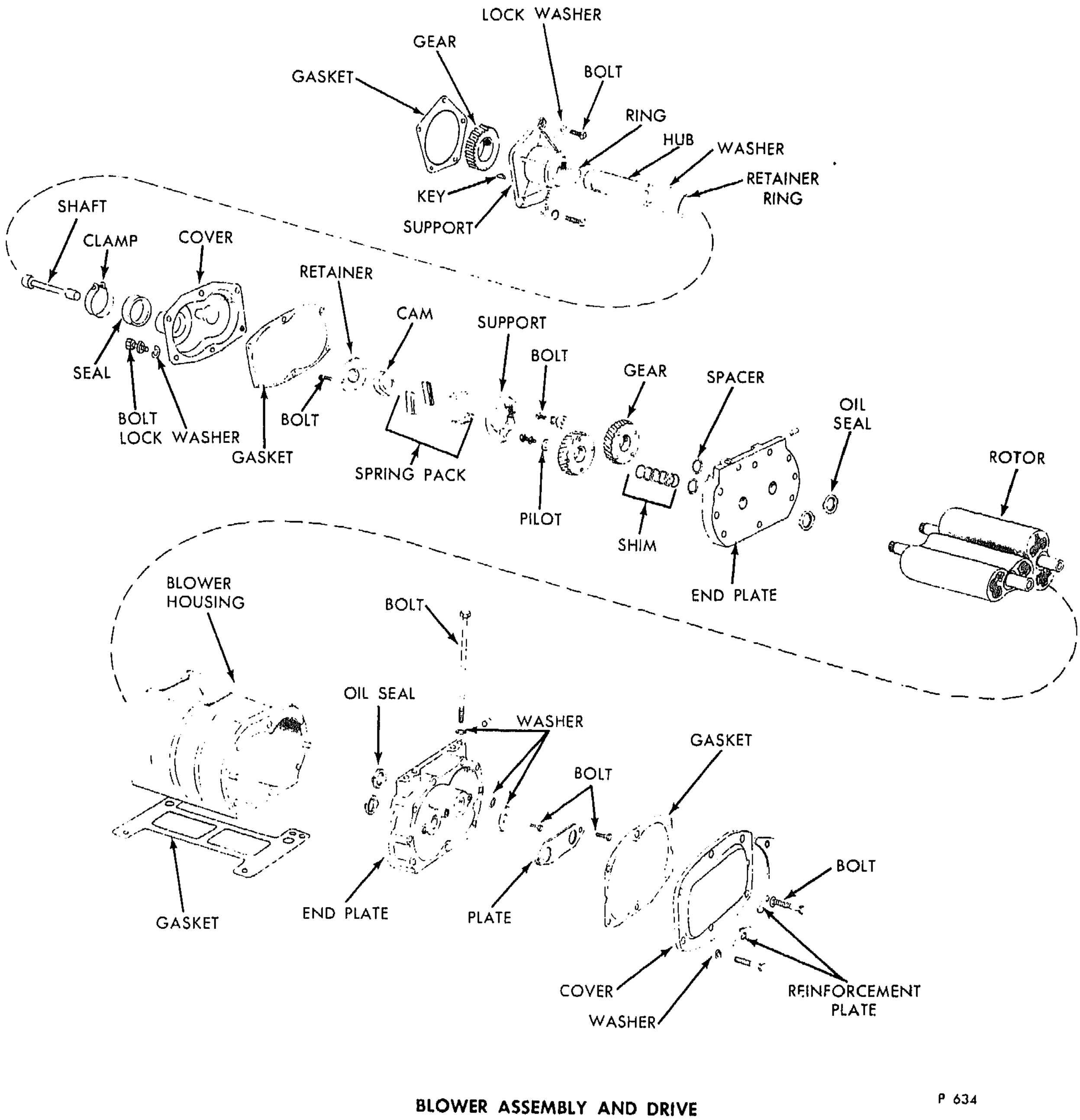
TYPICAL FUEL OIL FILTER



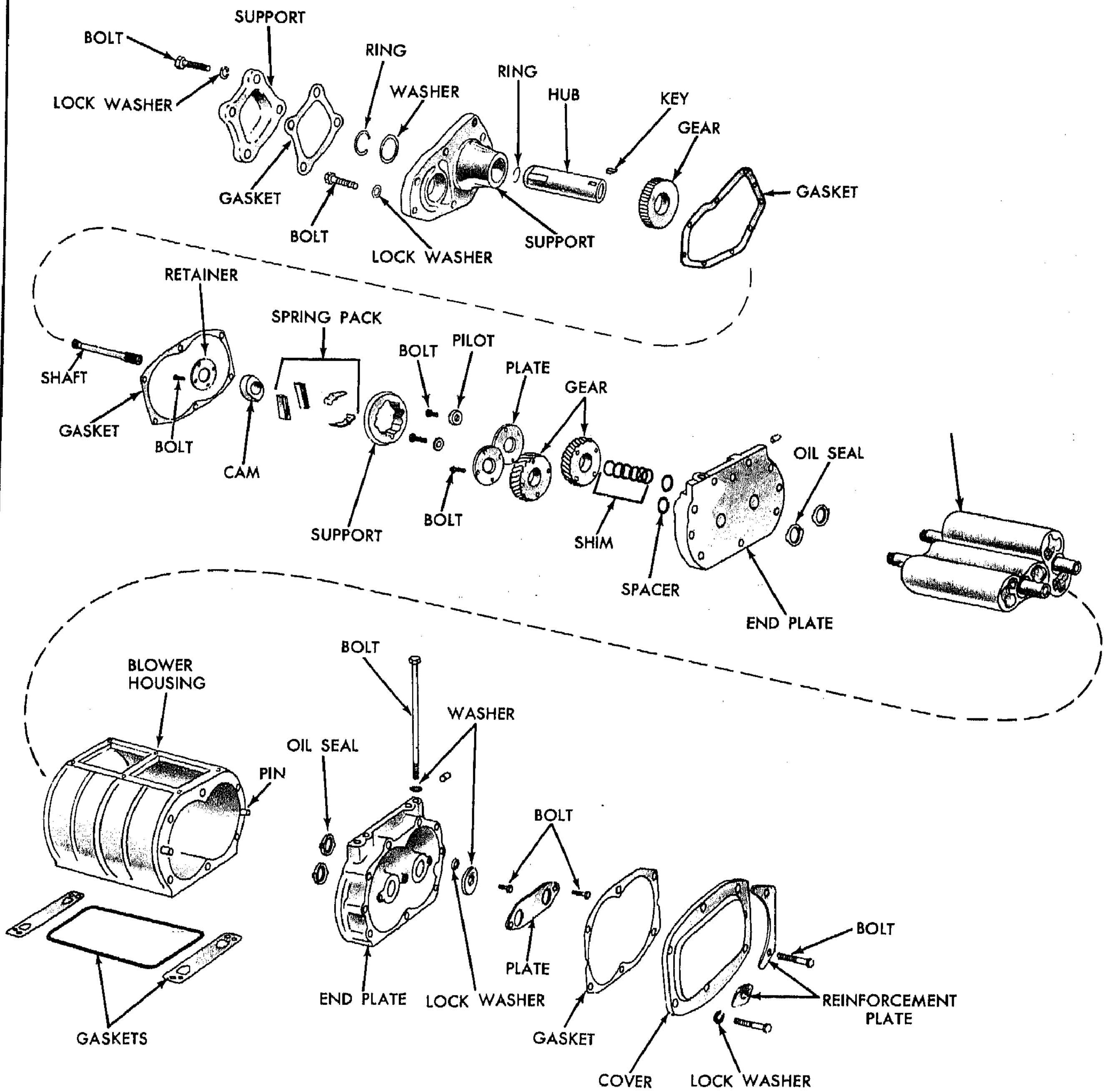
INJECTOR AND CONTROLS



AIR SHUT-DOWN HOUSING

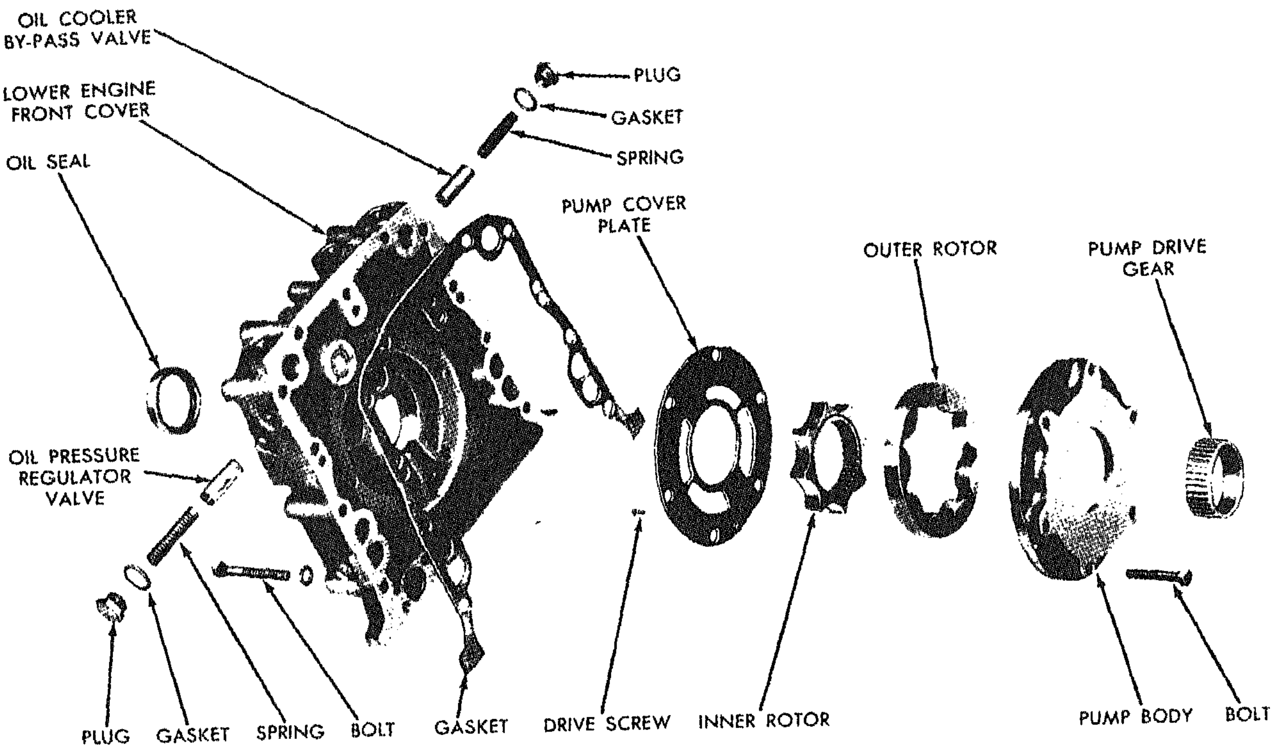


BLOWER ASSEMBLY AND DRIVE
(4 CYL.)

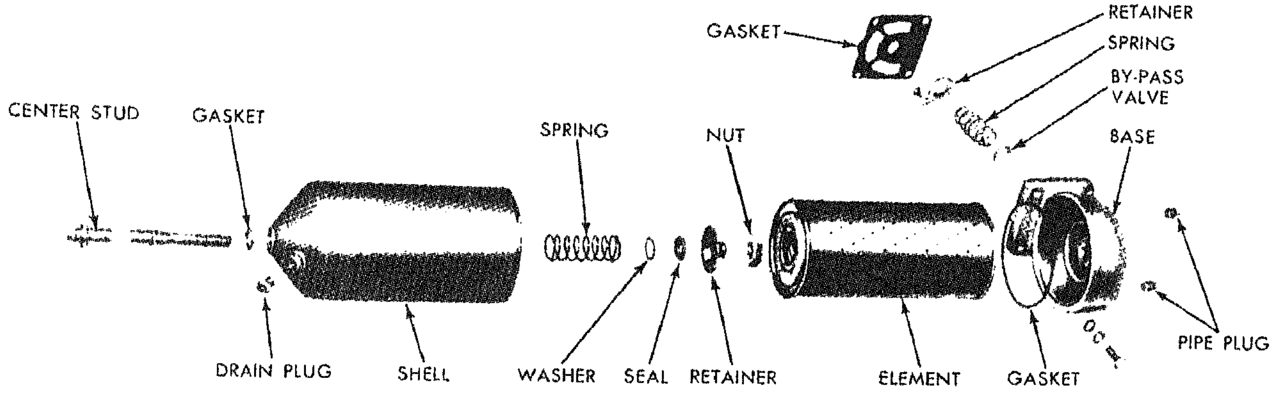


BLOWER ASSEMBLY AND DRIVE (6 CYL.)

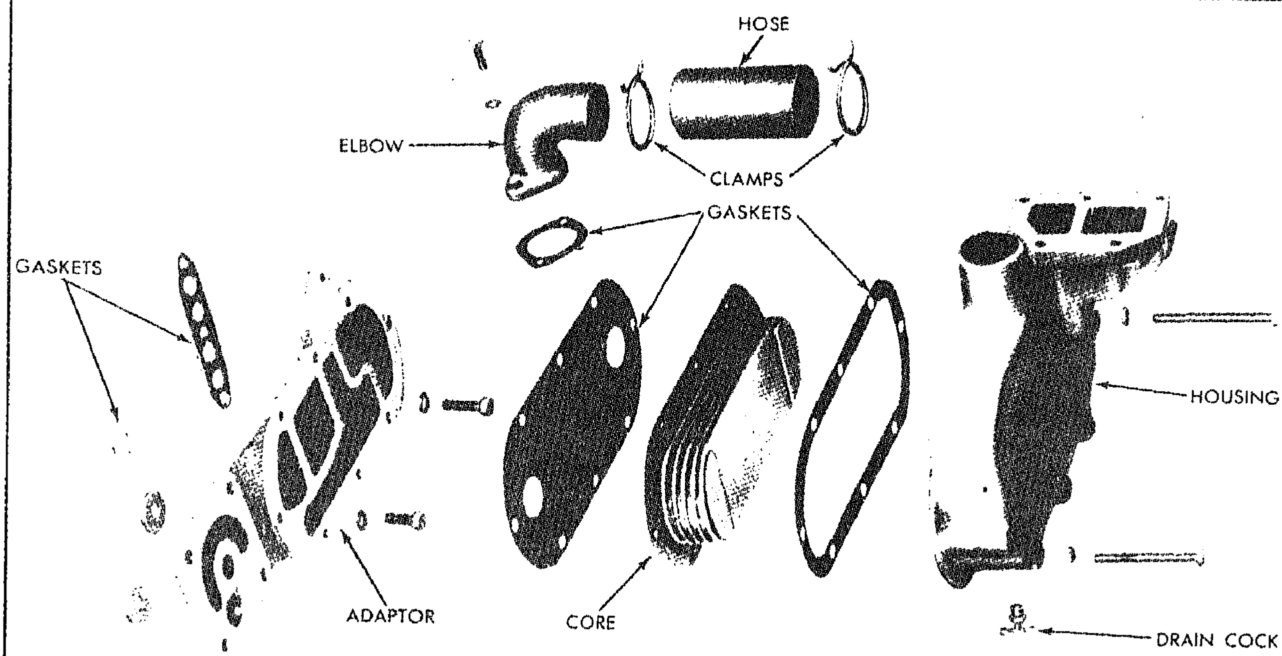
P 635



OIL PUMP AND REGULATOR

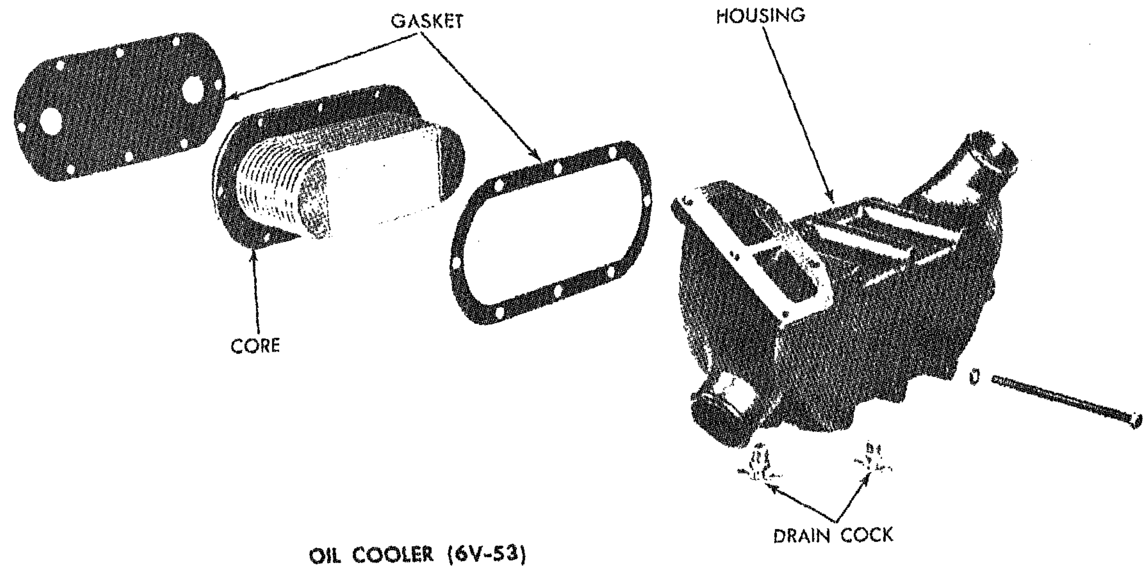


OIL FILTER

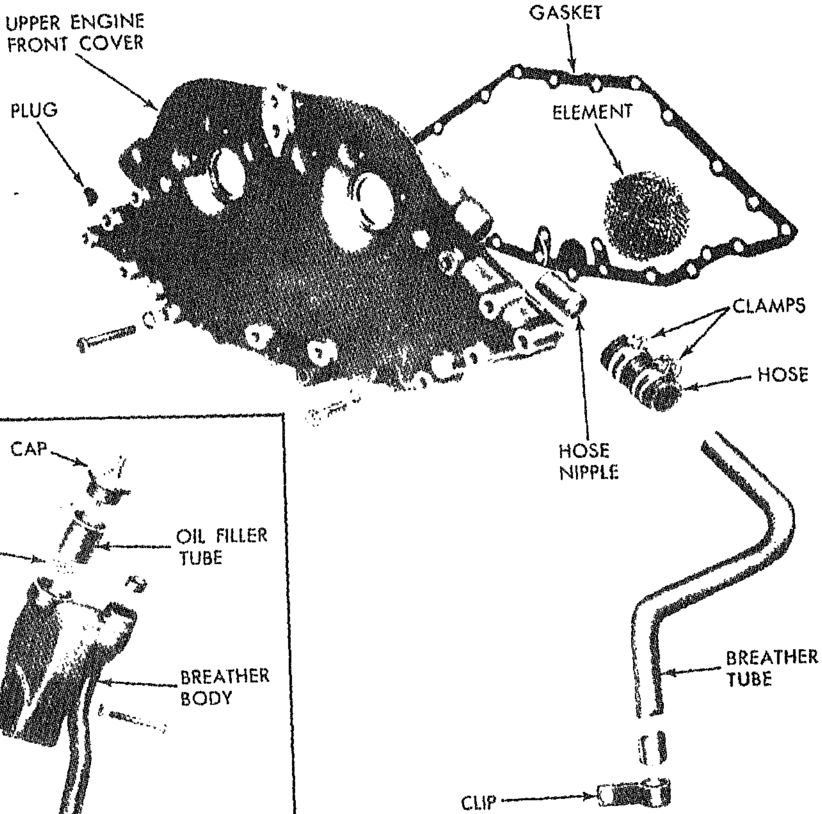


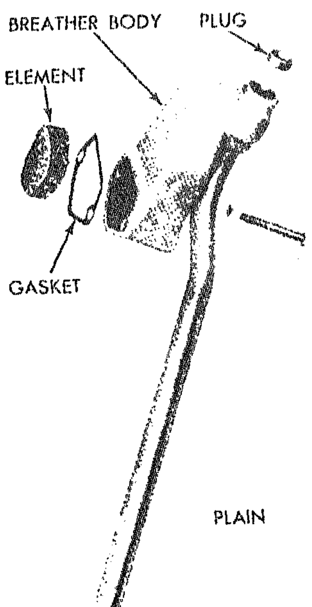
OIL COOLER

P 637



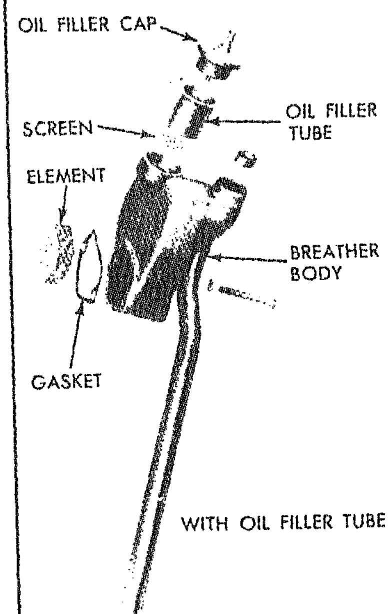
OIL COOLER (6V-53)





PLAIN

BREATHER

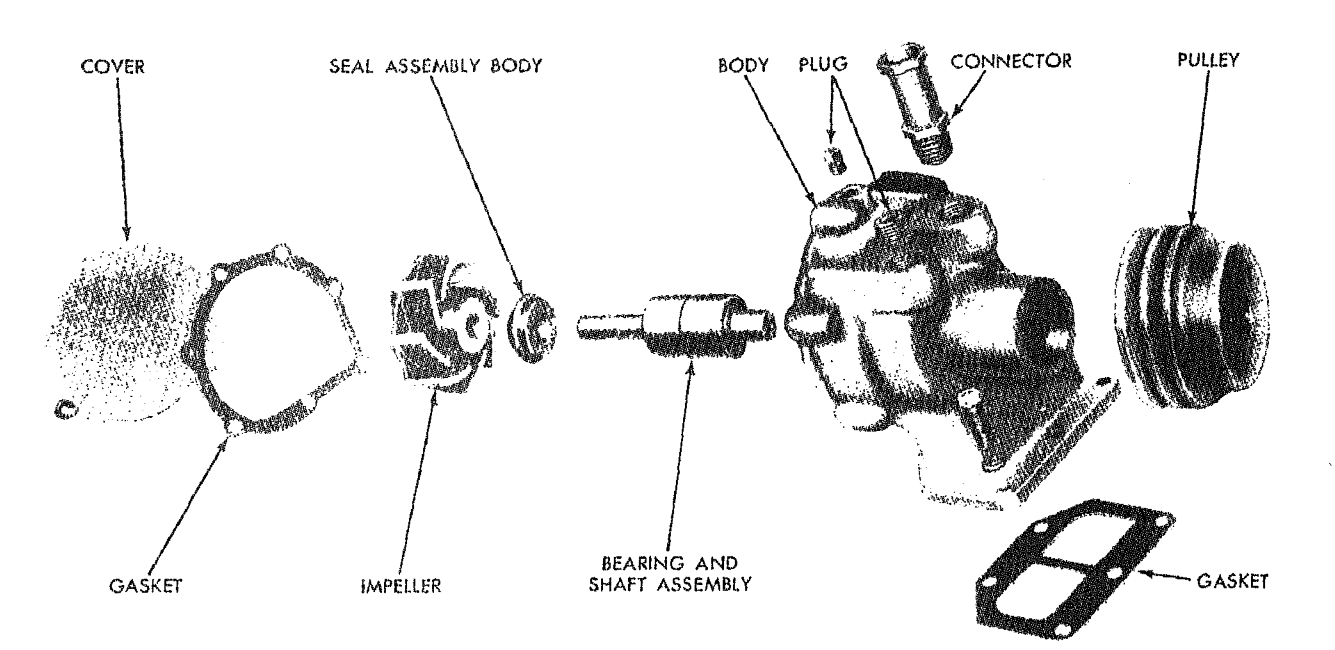


WITH OIL FILLER TUBE

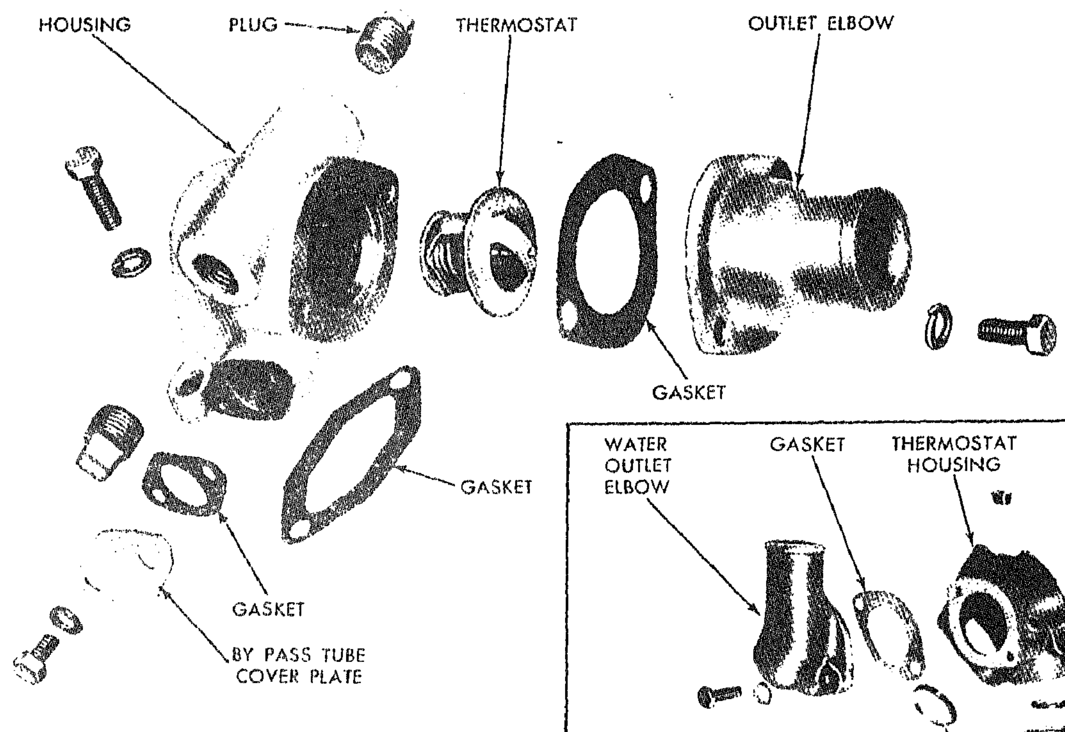
BREATHER

BREATHER (6V-53)

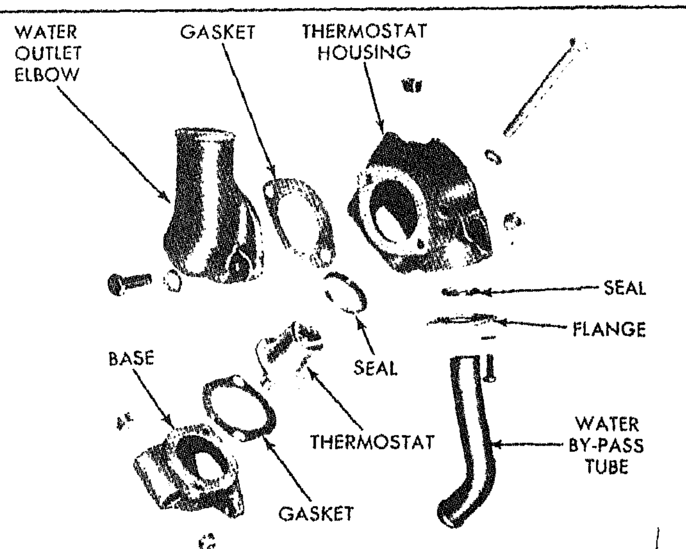
P 638



FRESH WATER PUMP

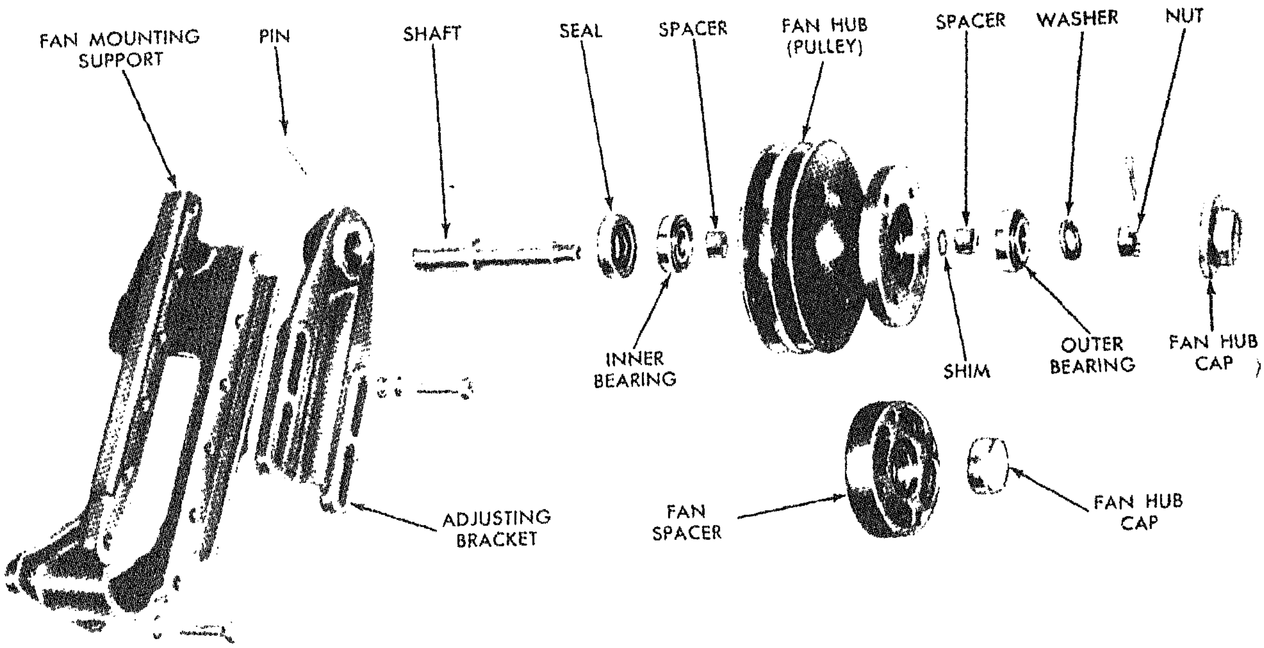


THERMOSTAT

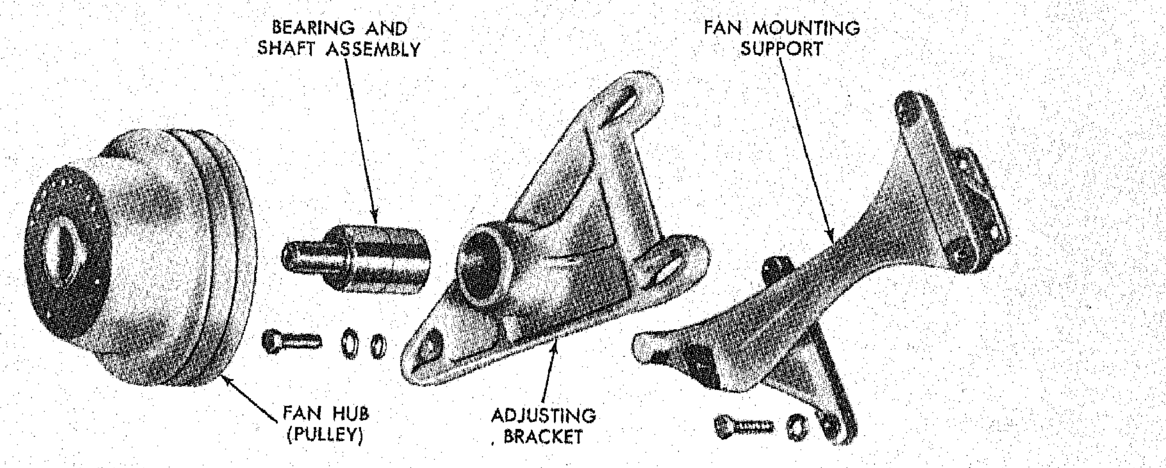


THERMOSTAT (6V-53)

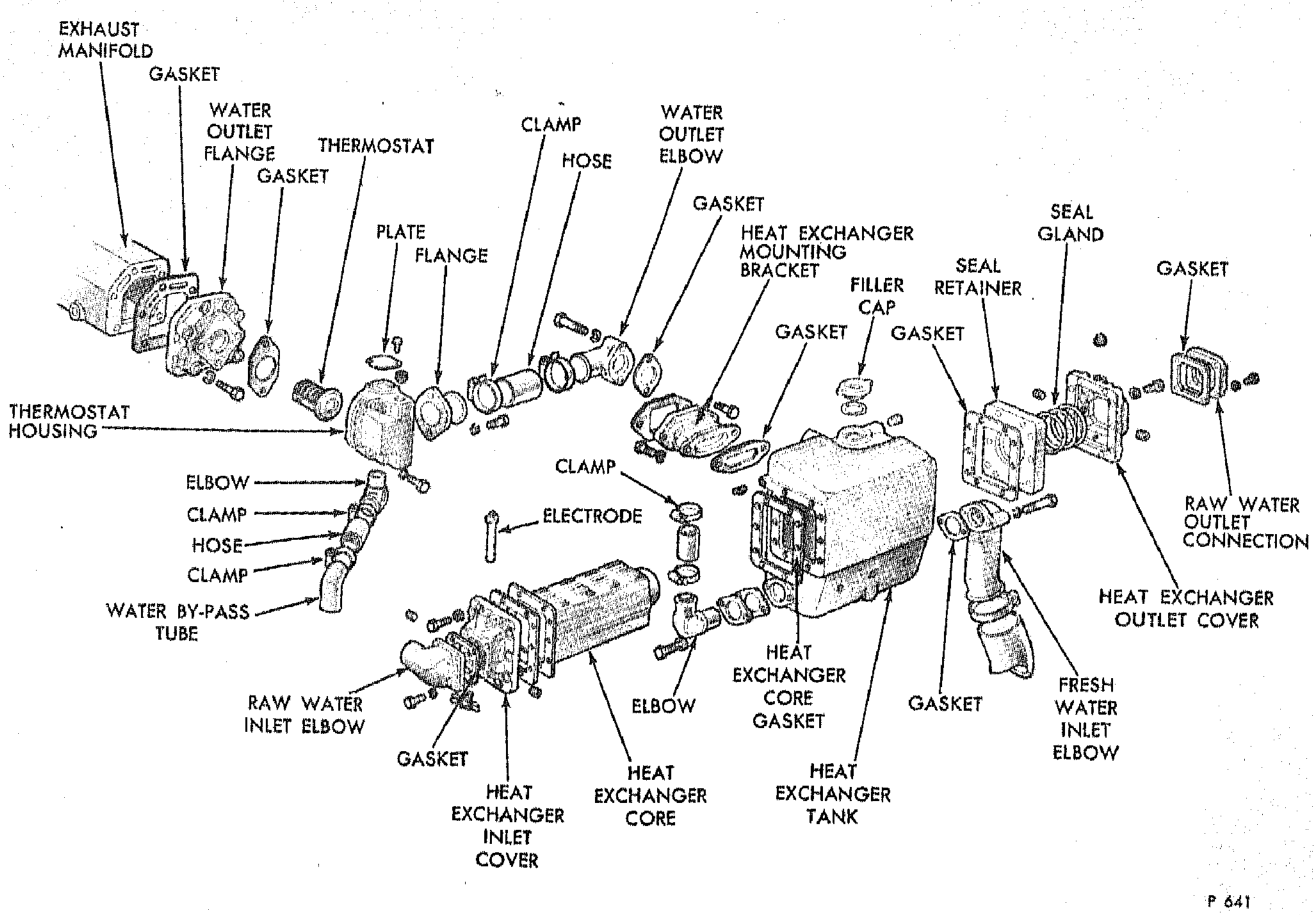
P 639



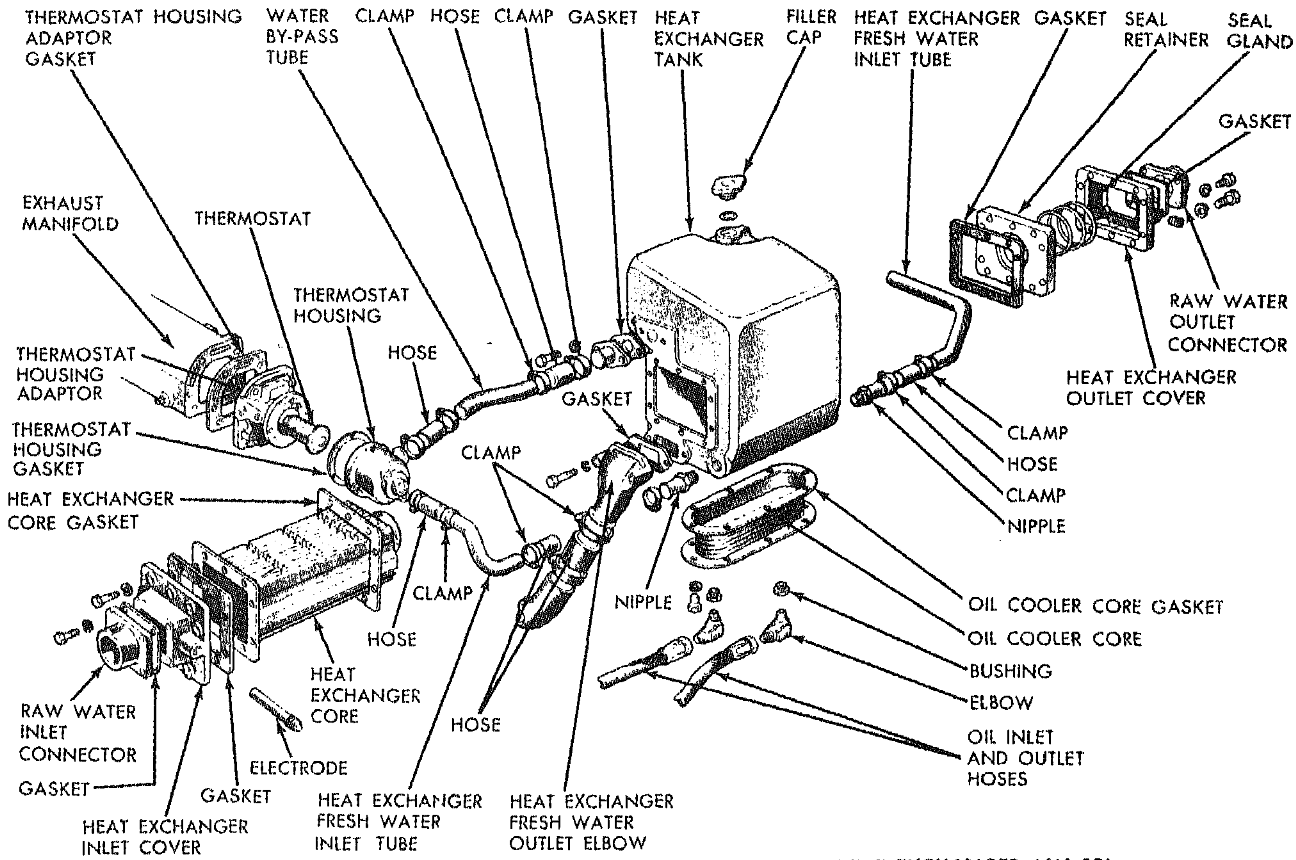
FAN MOUNT (6V-53)



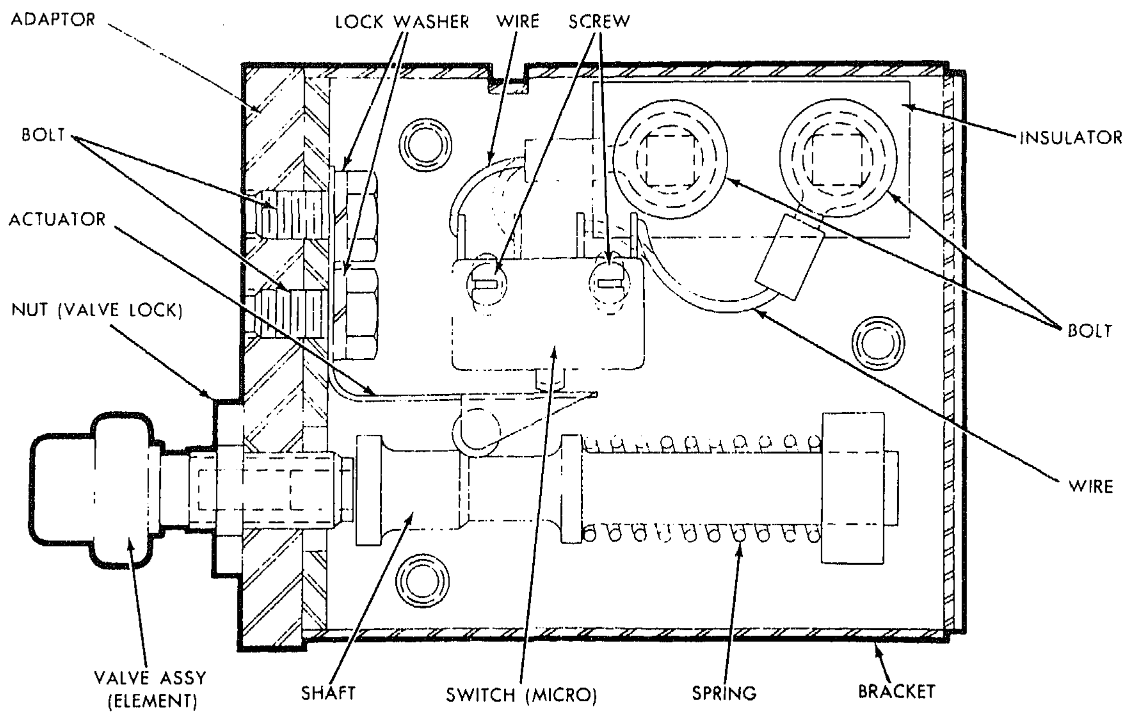
FAN MOUNT



HEAT EXCHANGER

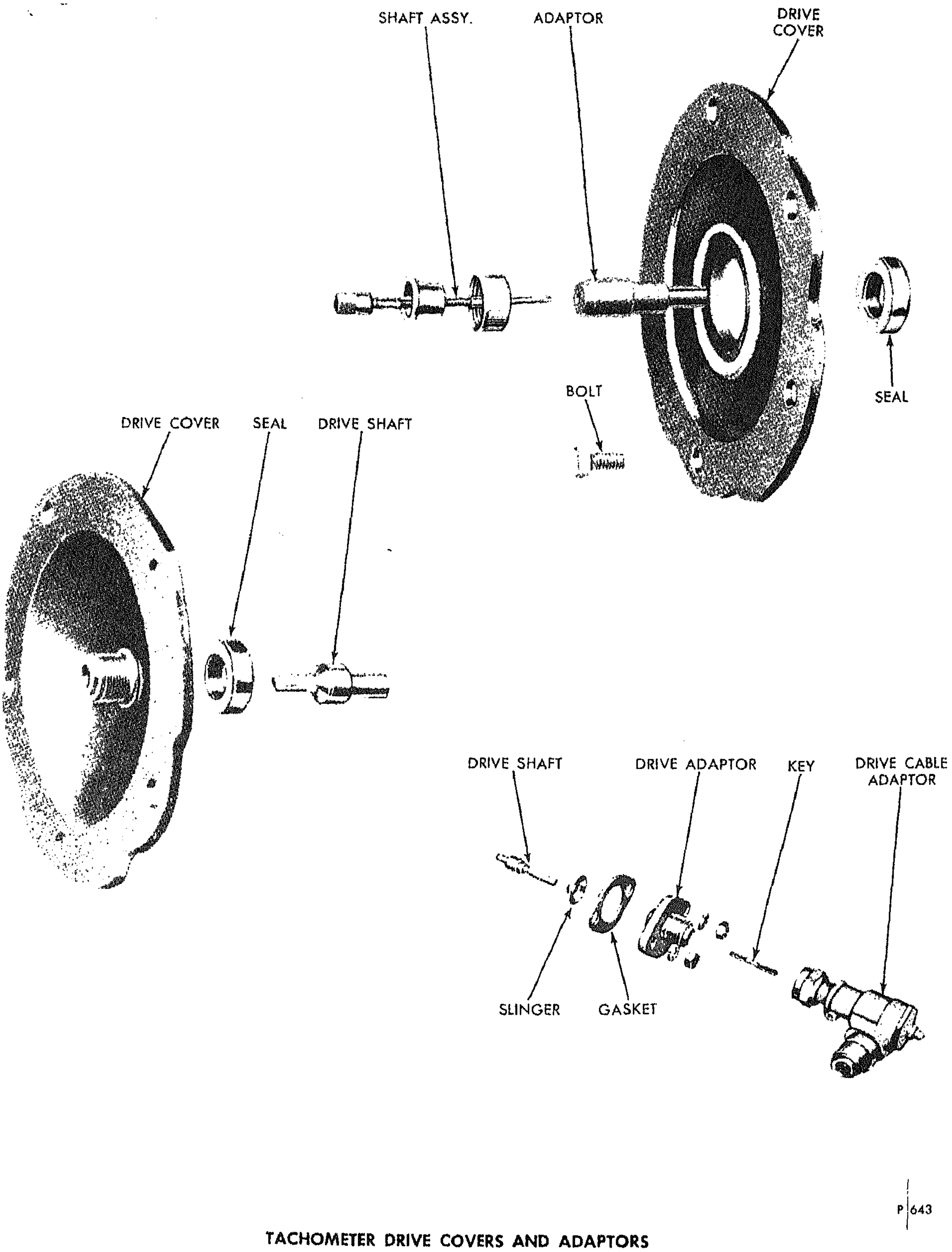


HEAT EXCHANGER (6V-53)

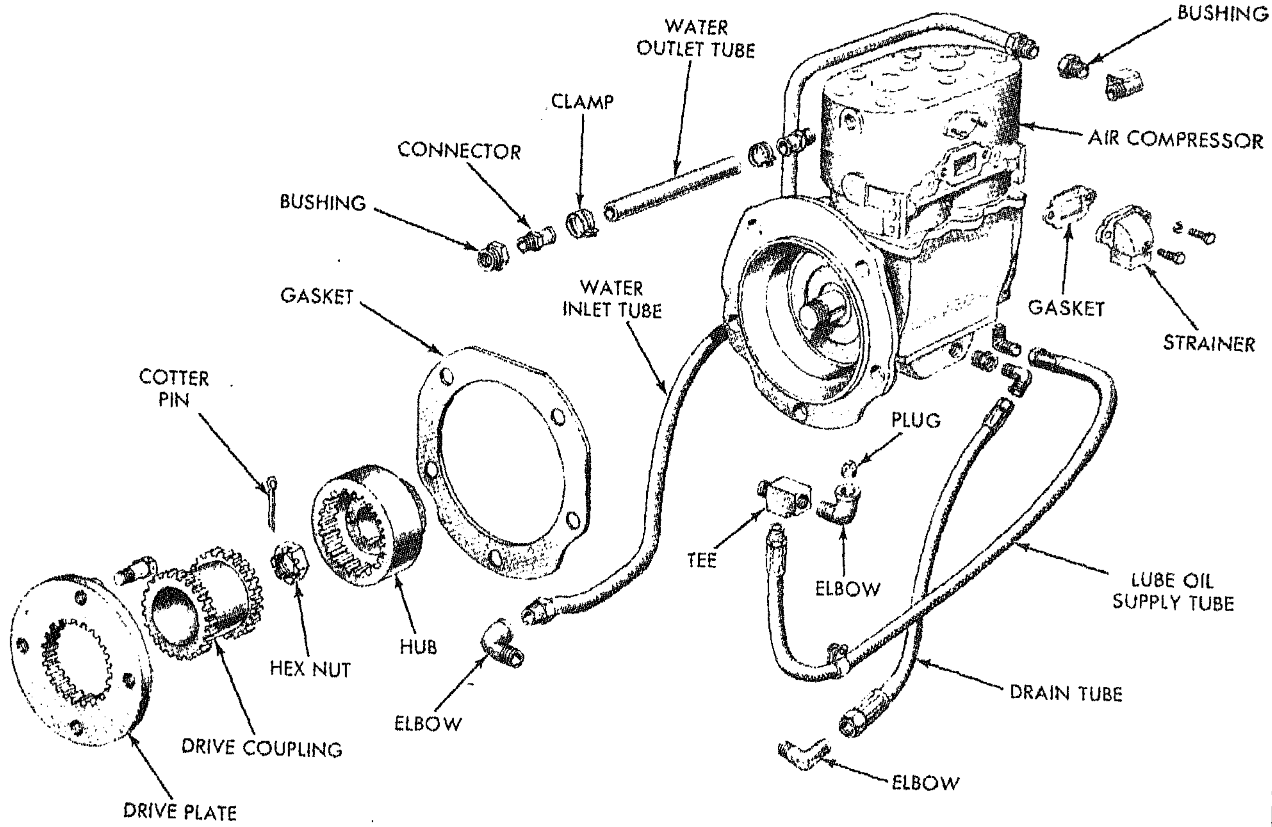


WATER TEMPERATURE SHUTDOWN SWITCH

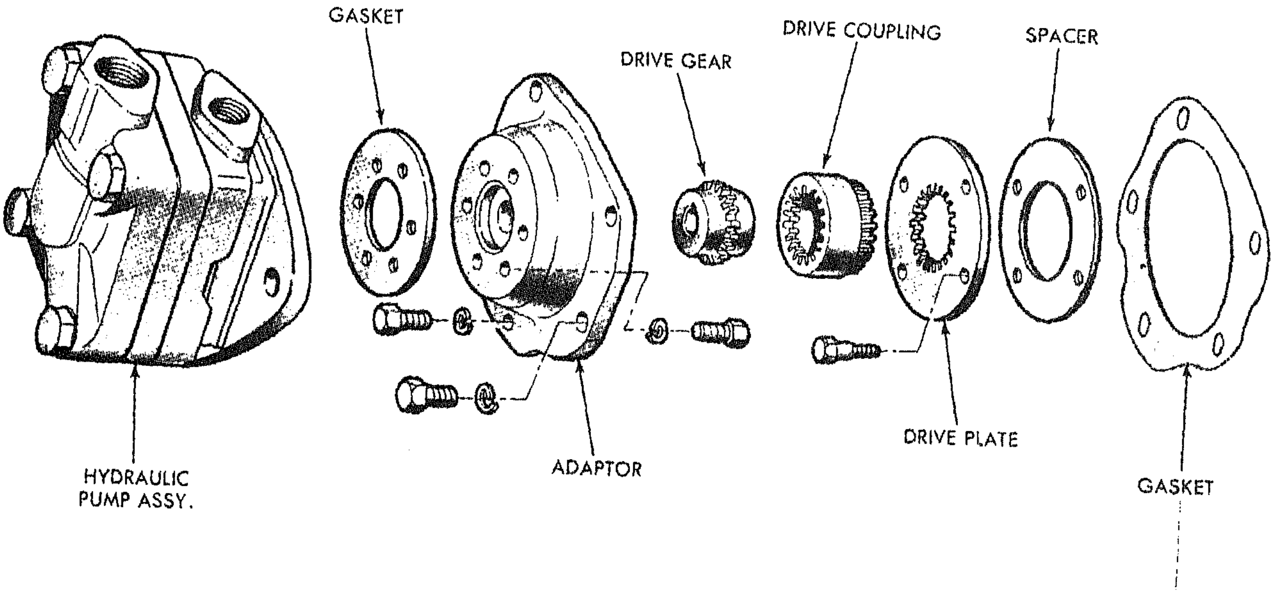
P 642



TACHOMETER DRIVE COVERS AND ADAPTORS



AIR COMPRESSOR AND DRIVE



HYDRAULIC PUMP AND DRIVE

P 644

OWNER ASSISTANCE

The satisfaction and goodwill of the owners of Detroit Diesel engines are of primary concern to the Detroit Diesel Allison Division, its distributors and their dealers.

Normally, any problem that arises in connection with the sale or operation of your engine will be handled by the distributor or dealer in your area. It is recognized, however, that despite the best intentions of everyone concerned, misunderstandings may occur. If you have a problem that has not been handled to your satisfaction, we suggest that you take the following steps:

Step One - **Discuss your problem with a member of management from the distributorship or dealership.** Frequently complaints are the result of a breakdown in communication and can quickly be resolved by a member of management. If you have already discussed the problem with the Sales or Service Manager, contact the General Manager. If your problem originates with a dealer, explain the matter to a management member of the distributorship with whom the dealer has his service agreement.

Step Two - When it appears that your problem cannot readily be resolved at the distributor level without additional assistance, **contact the Detroit Diesel Allison Regional Office nearest you** listed below:

Eastern Region
Suite 202
10 Parsonage Road
Edison, New Jersey 08817
Phone: (201) 246-5074
Regional Manager: W. E. Johnston
Service Manager: D. J. LaFave

Southeastern Region
5730 Glenridge Drive, N. E.
Atlanta, Georgia 30328
Phone: (404) 252-3310
Regional Manager: C. O. Zimmerman
Service Manager: L. R. Kirby

Great Lakes Region
Garrison Place
19855 Outer Drive
Dearborn, Michigan 48124
Phone: (313) 565-0411
Regional Manager: A. W. Christy
Service Manager: A. A. Voss

Midwestern Region
Suite 618
2021 Spring Road
Oak Brook, Illinois 60521
Phone: (312) 654-6600
Regional Manager: N. R. DeMaestri
Service Manager: Stanley Dobrasko

Southwestern Region
Suite 130
2655 Villa Creek Drive
Dallas, Texas 75234
Phone: (214) 241-7721
Regional Manager: F. A. Skells
Service Manager: W. C. Kaphengst

Western Region
Suite 345
1700 South El Camino Real
San Mateo, California 94402
Phone: (415) 341-9241
Regional Manager: W. C. Edwards
Service Manager: J. P. Miles

Prior to this call, have the following information available:

- Name and location of distributor (or dealer).
- Type and make of equipment.
- Engine model and serial number.
- Engine delivery date and accumulated miles or hours of operation.
- Nature of problem.
- Chronological summary of unit's history.

Step Three - If you are still not satisfied, **present the entire matter in writing or by phone to the Home Office:**

Diesel Operations - J. E. Fisher, Manager Customer Services, Detroit Diesel Allison, 13400 W. Outer Drive, Detroit, Michigan 48228, Phone (313) 592-5608.

Canada Operations - E. A. Kobe, Manager of Product Service, Diesel Division, General Motors of Canada, Ltd., P.O. Box 5990, 847 Highbury Avenue, London, Ontario N6A 4L6, Phone (519) 455-7110.

The inclusion of all pertinent information will assist the Home Office in expediting the handling of the matter. If an additional review by the Home Office of all the facts involved indicates that some further action can be taken, the Regional Office will be so instructed.

If at this point your problem is still not resolved to your satisfaction, call or write: H. F. Wooster, Service Manager, Diesel Operations (313) 592-7279; D. F. Downham, Sales Manager, Diesel Operations (313) 592-7276.

When contacting the Regional or Home Office, please keep in mind that ultimately your problem will likely be resolved at the distributorship or dealership utilizing their facilities, equipment and personnel. Therefore, it is suggested that you follow the above steps in sequence when experiencing a problem.

Your purchase of a Detroit Diesel engine is greatly appreciated and it is our sincere desire to assure complete satisfaction.

ALPHABETICAL INDEX

ALPHABETICAL INDEX

ENGLISH TO METRIC CONVERSIONS

Multiply	by	to get equivalent number of:
LENGTH		
Inch	25.4	millimetres (mm)
Foot	0.304 8	metres (m)
Yard	0.914 4	metres
Mile	1.609	kilometres (km)
AREA		
$Inch^2$	645.2	$millimetres^2$ (mm^2)
	6.45	$centimetres^2$ (cm^2)
$Foot^2$	0.092 9	$metres^2$ (m^2)
$Yard^2$	0.836 1	$metres^2$
VOLUME		
$Inch^3$	16 387.	mm^3
	16.387	cm^3
	0.016 4	litres (l)
Quart	0.946 4	litres
Gallon	3.785 4	litres
$Yard^3$	0.764 6	$metres^3$ (m^3)
MASS		
Pound	0.453 6	kilograms (kg)
Ton	907.18	kilograms
Ton	0.907	tonne (t)
FORCE		
Kilogram	9.807	newtons (N)
Ounce	0.278 0	newtons
Pound	4.448	newtons

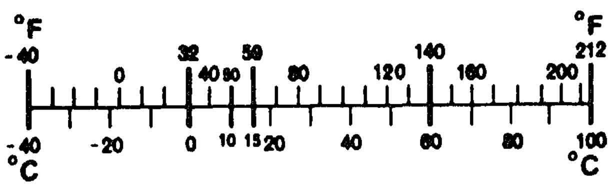
Multiply	by	to get equivalent number of:
ACCELERATION		
$Foot/sec^2$	0.304 8	$metre/sec^2$ (m/s^2)
$Inch/sec^2$	0.025 4	$metre/sec^2$
TORQUE		
Pound-inch	0.112 98	newton-metres (N·m)
Pound-foot	1.355 8	newton-metres
POWER		
Horsepower	0.746	kilowatts (kW)
PRESSURE OR STRESS		
Inches of mercury	3.377	kilopascals (kPa)
Inches of water	0.249 1	kilopascals
Pounds/sq. in.	6.895	kilopascals
ENERGY OR WORK		
BTU	1 055.	joules (J)
Foot-pound	1.355 8	joules
Kilowatt-hour	3.6×10^6 or 3 600 000	joules (J = one W·s)
LIGHT		
Footcandle	1.076 4	$lumens/metre^2$ (lm/m^2)
FUEL PERFORMANCE		
Miles/gal	0.425 1	kilometres/litre (km/l)
Gal/mile	2.352 7	litres/kilometre (l/km)
VELOCITY		
Miles/hour	1.609 3	kilometres/hr (km/h)

Degree (angle) 0.017 5 radians (rad)
Ounce (mass)-inch 720.077 8 milligram-metre (mg·m) (balancing)

TEMPERATURE

$°F = \frac{9}{5}(°C) + 32$

$°C = \frac{5}{9}(°F - 32)$



USE CONVERSION TABLES LIKE THIS:

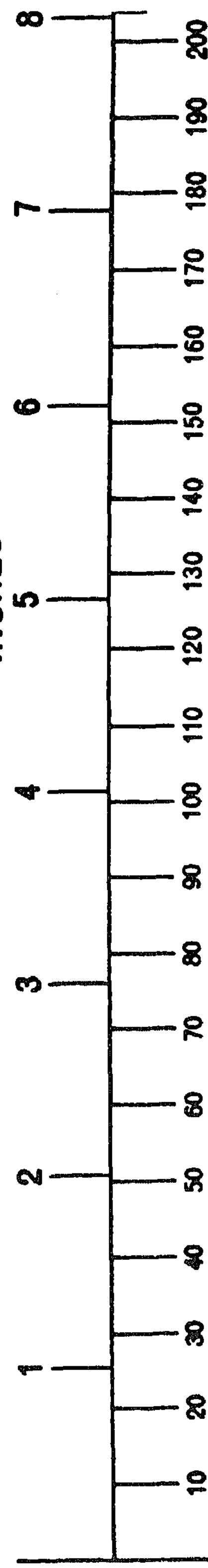
13 hp = ? kW Read across the 10 line to the 3 column. Read 9.7 kW

POWER – HORSEPOWER TO KILOWATTS

(1 hp = 0.7456999 kW)

hp	0	1	2	3	4	5	6	7	8	9
	kW	kW	kW	kW	kW	kW	kW	kW	kW	
0		0.75	1.49	2.24	2.98	3.73	4.47	5.22	5.9	
10	7.5	8.2	8.9	9.7	10.4	11.2	11.9	12.7		
20	14.9	15.7	16.4	17.2	17.9	18.6	19.4	[illegible]		
30	22.4	23.1	23.9	24.6	25.4	[illegible]	[illegible]			
[illegible]	[illegible]									

11883



PART II

Service Manual

Detroit Diesel Engines

SERIES 53

Printed in U.S.A.

FOREWORD

This manual contains instructions on the overhaul, maintenance and operation of the basic Series 53 Detroit Diesel Engines.

Full benefit of the long life and dependability built into these engines can be realized through proper operation and maintenance. Of equal importance is the use of proper procedures during engine overhaul.

Personnel responsible for engine operation and maintenance should study the sections of the manual pertaining to their particular duties. Similarly, before beginning a repair or overhaul job, the serviceman should read the manual carefully to familiarize himself with the parts or sub-assemblies of the engine with which he will be concerned.

The information, specifications and illustrations in this publication are based on the information in effect at the time of approval for printing. This publication is revised and reprinted periodically. It is recommended that users contact an authorized *Detroit Diesel Service Outlet* for information on the latest revisions. The right is reserved to make changes at any time without obligation.

TABLE OF CONTENTS

March, 1973

SCOPE AND USE OF THE MANUAL

This manual covers the basic Series 53 Diesel Engines built by the Detroit Diesel Allison Division of General Motors Corporation. Complete instructions on operation, adjustment (tune-up), preventive maintenance and lubrication, and repair (including complete overhaul) are covered. The manual was written primarily for persons servicing and overhauling the engine and, in addition, contains all of the instructions essential to the operators and users. Basic maintenance and overhaul procedures are common to all Series 53 engines and therefore apply to all engine models.

The manual is divided into numbered sections. The first section covers the engine (less major assemblies). The following sections cover a complete system such as the fuel system, lubrication system or air system. Each section is divided into sub-sections which contain complete maintenance and operating instructions for a specific sub-assembly on the engine. For example, Section 1, which covers the basic engine, contains sub-section 1.1 pertaining to the cylinder block, sub-section 1.2 covering the cylinder head, etc. The subjects and sections are listed in the Table of Contents on the preceding page. Pages are numbered consecutively, starting with a new Page 1 at the beginning of each sub-section. The illustrations are also numbered consecutively, beginning with a new Figure 1 at the start of each sub-section.

Information regarding a general subject, such as the lubrication system, can best be located by using the Table of Contents. Opposite each subject in the Table of Contents is a section number which registers with a tab printed on the first page of each section throughout the manual. Information on a specific sub-assembly or accessory can then be found by consulting the list of contents on the first page of the section. For example, the cylinder liner is part of the basic engine, therefore, it will be found in Section 1. Looking down the list of contents on the first page of Section 1, the cylinder liner is found to be in sub-section 1.6.3. An Alphabetical Index at the back of the manual has been provided as an additional aid for locating information.

SERVICE PARTS AVAILABILITY

Genuine Detroit Diesel "Factory Engineered" replacement parts are available from authorized Detroit Diesel Service Outlets conveniently located within the United States, in Canada from the distribution organization of Diesel Division, General Motors of Canada Limited, and abroad through the sales and service outlets of General Motors Overseas Operations Divisions.

CLEARANCES AND TORQUE SPECIFICATIONS

Clearances of new parts and wear limits on used parts are listed in tabular form at the end of each section throughout the manual. It should be specifically noted that the "New Parts" clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still assure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the paragraph entitled *Inspection* under *General Procedures* in this section.

Bolt, nut and stud torque specifications are also listed in tabular form at the end of each section.

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively as shown in Fig. 1. In contrast, a four-cycle engine requires four piston strokes to complete an operating cycle; thus, during one half of its operation, the four-cycle engine functions merely as an air pump.

A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports as shown in Fig. 1 (scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression as shown in Fig. 1 (compression).

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector as shown in Fig. 1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about half way down, allowing the burned gases to escape into the exhaust manifold as shown in Fig. 1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, in two strokes; hence, it is a "two-stroke cycle".

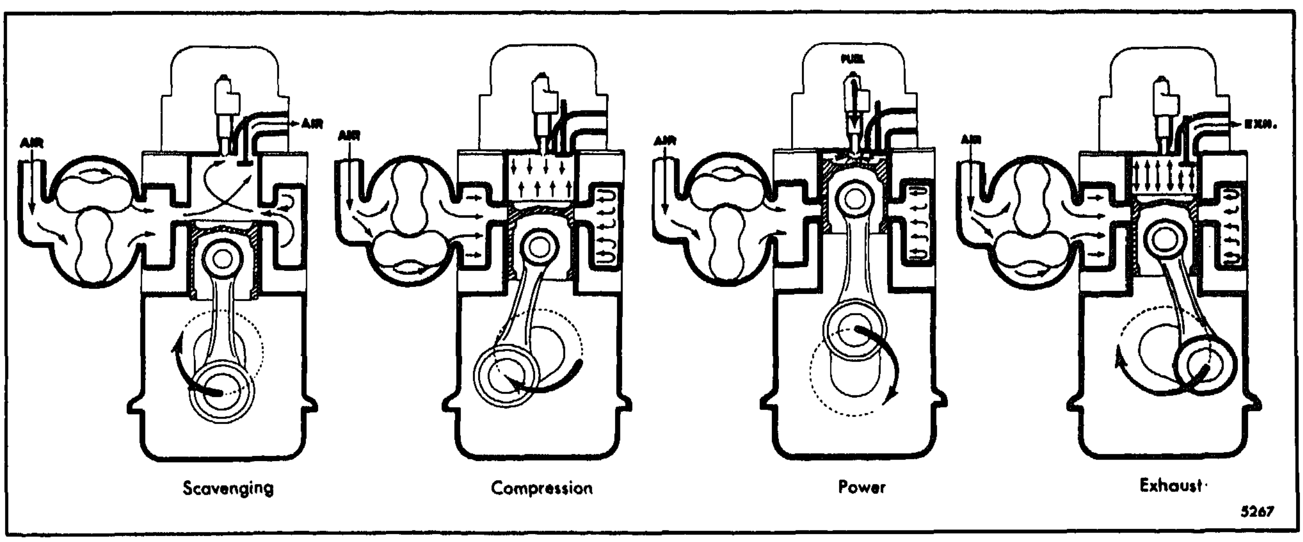


Fig. 1 - The Two Stroke Cycle

GENERAL DESCRIPTION

The two-cycle diesel engines covered in this manual have the same bore and stroke and many of the major working parts such as injectors, pistons, connecting rods, cylinder liners and other parts are interchangeable.

The In-line engines, including the inclined marine models, include standard accessories such as the blower, water pump, governor and fuel pump, which, on some models, may be located on either side of the engine regardless of the direction the crankshaft rotates. Further flexibility in meeting installation requirements is achieved with the cylinder head which can be installed to accommodate the exhaust manifold on either side of the engine.

The V-type engines use many In-line engine parts, including the 3-53 and 4-53 cylinder heads. The blower is mounted on top of the engine between the two banks of cylinders and is driven by the gear train. The governor is mounted on the rear end of the 6V-53 blower and on the front end of the 8V-53 blower.

The meaning of each digit in the model numbering system is shown in Figs. 2 and 3. The letter L or R indicates left or right-hand engine rotation as viewed from the front of the engine. The letter A, B, C or D designates the blower and exhaust manifold location on the In-line engines as viewed from the rear of the engine while the letter A or C designates the location of the oil cooler and starter on the V-type engines.

Each engine is equipped with an oil cooler (not required on certain two-cylinder models), full-flow oil filter, fuel oil strainer and fuel oil filter, an air cleaner or silencer, governor, heat exchanger and raw water pump or fan and radiator, and a starting motor.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings and to other moving parts. A rotor-type pump on In-line or 6V engines or a gear-type pump on 8V engines draws oil from the oil pan through a screen and delivers it to the oil filter. From the filter, the oil flows to the oil cooler and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the camshaft bearings and up through the rocker arm assemblies; the remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft.

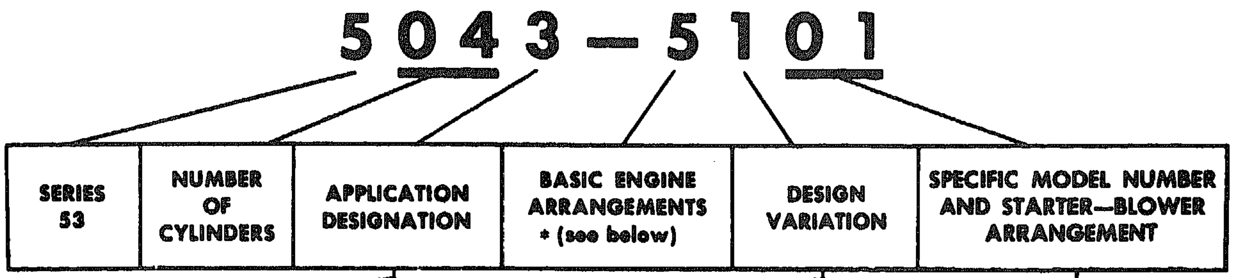
Coolant is circulated through the engine by a centrifugal-type water pump. Heat is removed from the coolant, which circulates in a closed system, by the heat exchanger or radiator. Control of the engine temperature is accomplished by thermostat(s) which regulate the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the fuel strainer by a gear-type fuel pump. It is then forced through a filter and into the fuel inlet manifold in the cylinder head(s) and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifold and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air for scavenging and combustion is supplied by a blower which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower first passes through an air cleaner or silencer.

Engine starting is provided by either a hydraulic or electric starting system. The electric starting motor is energized by a storage battery. A battery-charging generator, with a suitable voltage regulator, serves to keep the battery charged.

Engine speed is regulated by a mechanical or hydraulic type engine governor, depending upon the engine application.



APPLICATION DESIGNATION

5042-5100	MARINE
5043-5100	FAN TO F/W—INDUSTRIAL
5044-5100	POWER-BASE
5045-5100	GENERATOR
5047-5100	FAN TO F/W—VEHICLE

DESIGN VARIATION

5043-5000	"N" ENGINE
5043-5100	2 VALVE HEAD
5043-5200	4 VALVE HEAD
5042-2302	TURBOCHARGER

STARTER—BLOWER ARRANGEMENT

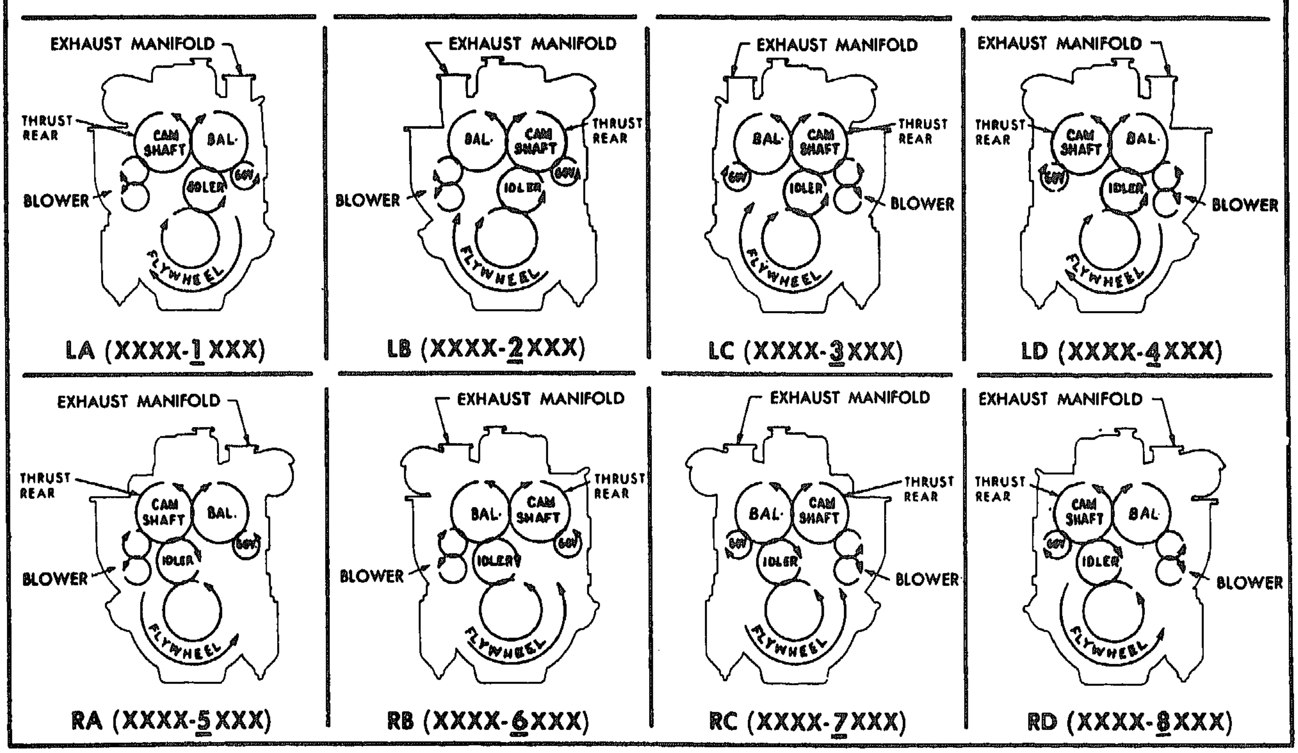
Odd number in last digit designates starter opposite blower.

Even number in last digit designates starter same side as blower.

*** 2, 3, 4-53 BASIC ENGINE ARRANGEMENTS**

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A-B-C-D designates location of exhaust manifold and blower as viewed from the flywheel end of the engine.



ALL ABOVE VIEWS FROM REAR (FLYWHEEL) END OF ENGINE

2003

Fig. 2 - In-line Engine Model Description, Rotation, and Accessory Arrangements

5063 — 5200

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENT * (see below)	DESIGN VARIATION	SPECIFIC MODEL NUMBER

APPLICATION DESIGNATION

5062-3000 MARINE
5063-5200 FAN to F/W-INDUSTRIAL
5064-5200 POWER-BASE
5065-5200 GENERATOR
5067-5040 FAN to F/W VEHICLE
5082-5000 MARINE
5083-5000 FAN to F/W INDUSTRIAL
5087-5040 FAN to F/W VEHICLE

DESIGN VARIATION

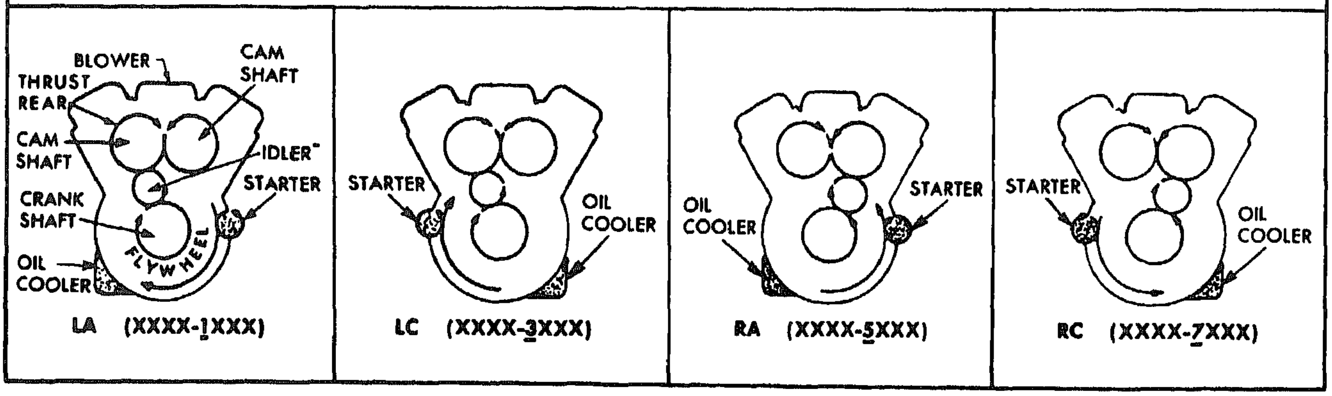
5062-3000 "N" ENGINE
5063-5200 4 VALVE HEAD

* **BASIC ENGINE ARRANGEMENTS**

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A and C designates location of starter and oil cooler as viewed from the flywheel end of the engine.

Cylinder Bank: Left and right cylinder banks are determined from the flywheel end of the engine.



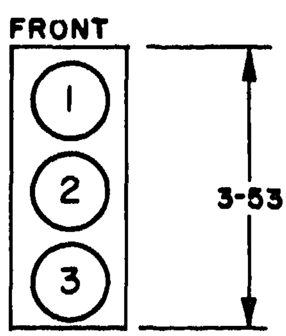
ALL ABOVE VIEWS FROM REAR FLYWHEEL END OF ENGINE

4017

Fig. 3 · 6 and 8V Engine Model Description, Rotation and Accessory Arrangement

GENERAL SPECIFICATIONS

		3-53
Type		2 Cycle
Number of Cylinders		3
Bore		3.875 in.
Stroke		4.5 in.
Compression Ratio (Nominal) (Standard Engines).		17 to 1
Compression Ratio (Nominal) ("N" Engines) . .		21 to 1
Total Displacement - Cubic Inches		159
Number of Main Bearings		4



3 -53

FIRING ORDER

3-53 RH - 1-3-2

Fig. 4 - Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION PLATE

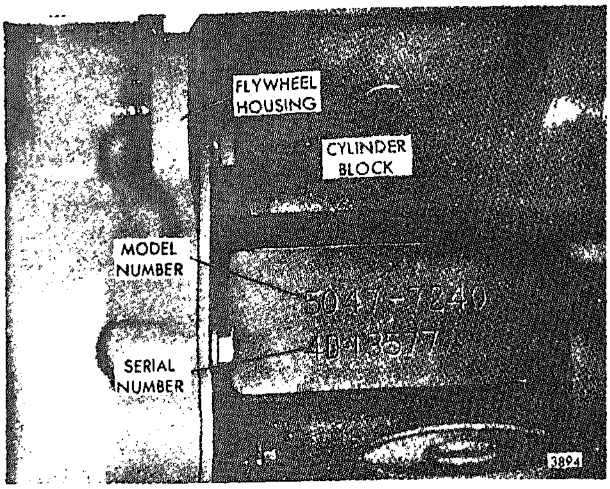


Fig. 5 - Typical Model and Serial Numbers as Stamped on Cylinder Block (In-Line Engine)

On the In-line engines, the model number and serial number are stamped on the right-hand side of the cylinder block in the upper rear corner (Fig. 5).

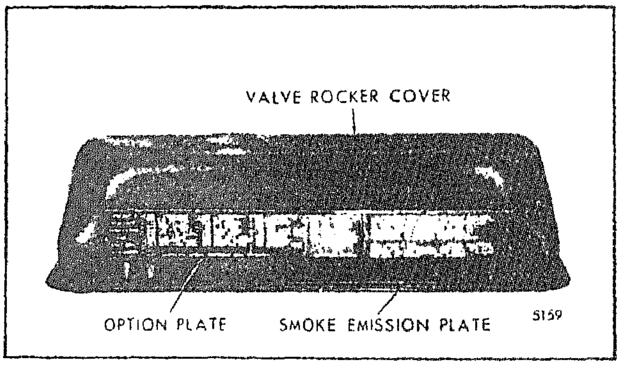


Fig. 7 - Option Plate

An option plate, attached to the valve rocker cover, is also stamped with the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 7). Where required, a smoke emission certification plate is installed next to the option plate.

With any order for parts, the engine model number and serial number must be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

All groups of parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

Power take-off assemblies, torque converters, marine gears, etc. may also carry name plates. The information on these name plates is also useful when ordering replacement parts for these assemblies.

GENERAL PROCEDURES

In many cases, a serviceman is justified in replacing parts with new material rather than attempting repair. However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Crankshafts, cylinder liners and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse, thereby saving the expense of a new part. Exchange assemblies such as injectors, fuel pumps, water pumps and blowers are also desirable service items.

Various factors such as the type of operation of the engine, hours in service and next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble- free operation.

For convenience and logical order in disassembly and assembly, the various sub-assemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, coolant and fuel. On engines cooled by a heat exchanger, the fresh water system and raw water system must both be drained. Lubricating oil should also be drained from any transmission attached to the engine.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various sub-assemblies should be removed from the engine. When only a few items need replacement, it is not always necessary to mount the engine on an overhaul stand.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suitable wooden racks or blocks, or a parts dolly.

CLEANING

Before removing any of the sub-assemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each sub-assembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is outlined under *Clean Cylinder Block* in Section 1.1; any special cleaning procedures will be mentioned in the text wherever required.

Steam Cleaning

A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its sub-assemblies.

Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 180 ° F.-200 ° F.

Fill the tank with a commercial heavy-duty solvent which is heated to the above temperature. Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

Drying

Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete drying of the parts without the use of compressed air.

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in an engine.

INSPECTION

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector.

The guiding factors in determining the usability of worn parts, which are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize and/or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets which include all of the parts necessary to complete a particular repair job are available.

A complete discussion of the proper methods of precision measuring and inspection are outside the scope of this manual. However, every shop should be equipped with standard gages, such as dial bore gages, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other defects.

ASSEMBLY

Following cleaning and inspection, the engine should be assembled using new parts as determined by the inspection.

Use of the proper equipment and tools makes the job progress faster and produces better results. Likewise, a suitable working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment and space will be repaid many times.

Keep the working space, the equipment, tools and engine assemblies and parts clean at all times. The area where assembly operations take place should, if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should be removed as far as possible from the assembly area.

Particular attention should be paid to storing of parts and sub-assemblies, after removal and cleaning and prior to assembly, in such a place or manner as to keep them clean. If there is any doubt as to the cleanliness of such parts, they should be recleaned.

When assembling an engine or any part thereof, refer to the table of torque specifications at the end of each section for proper bolt, nut and stud torques.

WORK SAFELY

A serviceman can be severely injured if caught in the pulleys, belts or fan of an engine that is accidentally started. To avoid such a misfortune, take these precautions before starting to work on an engine:

Disconnect the battery from the starting system by removing one or both of the battery cables. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.

Make sure the mechanism provided at the governor for stopping the engine is in the stop position. This will mean the governor is in the no-fuel position. The possibility of the engine firing by accidentally turning the fan or, in the case of vehicle application, by being bumped by another vehicle is minimized.

Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.

2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

3. Always use caution when using power tools.

4. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury.

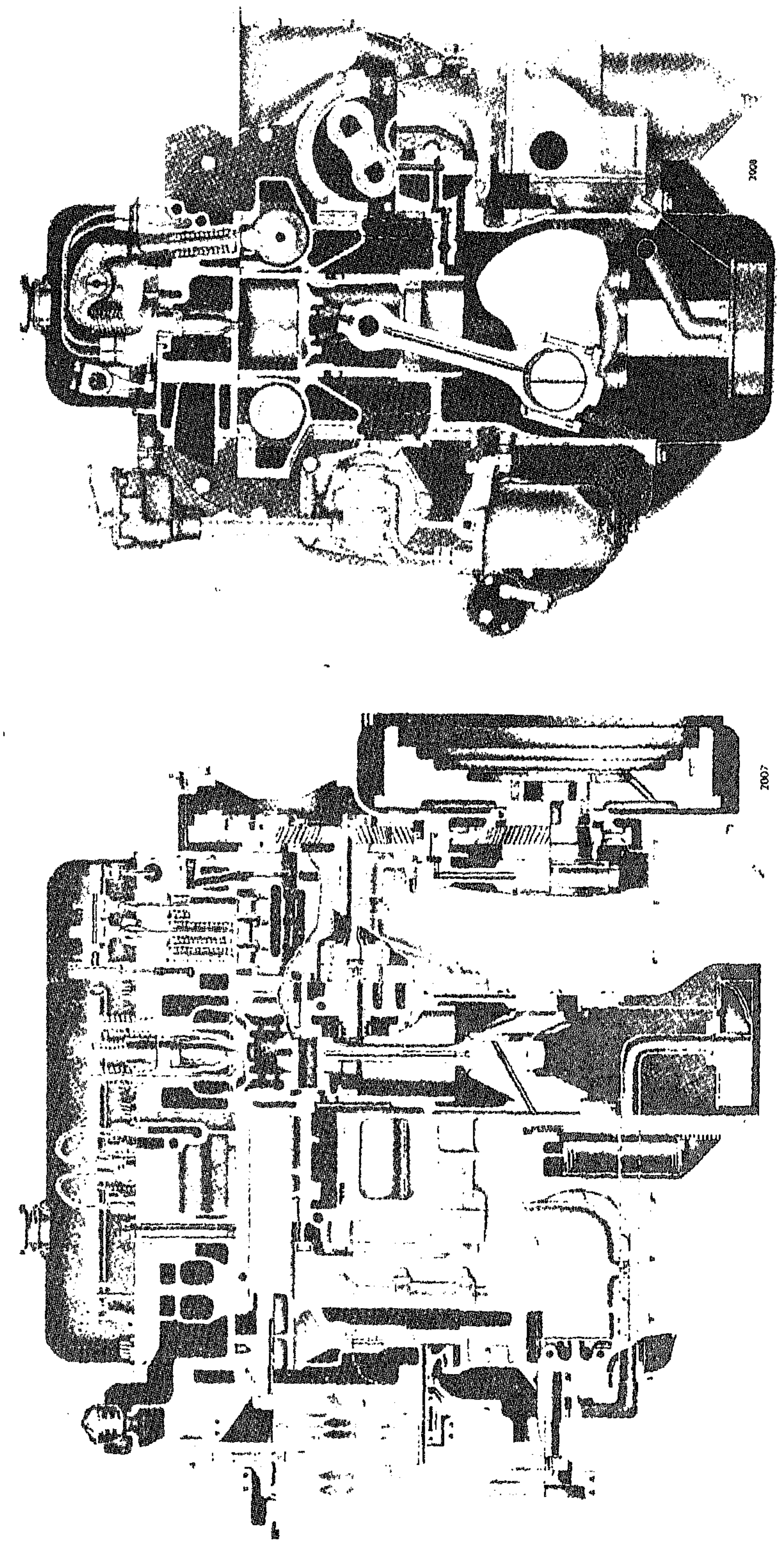
5. Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichlorethylene. However, while less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield, and apron.

Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

6. Use caution when welding on or near the fuel tank. Possible explosion could result if heat build-up inside the tank is sufficient.

7. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

8. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.



Cross Sections of a Typical In-Line Engine

SECTION 1

ENGINE (less major assemblies)

CONTENTS

CYLINDER BLOCK

The cylinder block (Fig . 1) serves as the main structural part of the engine. Transverse webs provide rigidity and strength and ensure alignment of the block bores and bearings under load. Cylinder blocks for the two, three and four cylinder In-Line engines are identical in design and dimensions except for length.

The block is bored to receive replaceable wet-type cylinder liners. On the In-Line and 6V cast iron cylinder blocks, a water jacket surrounds the upper half of each cylinder liner.

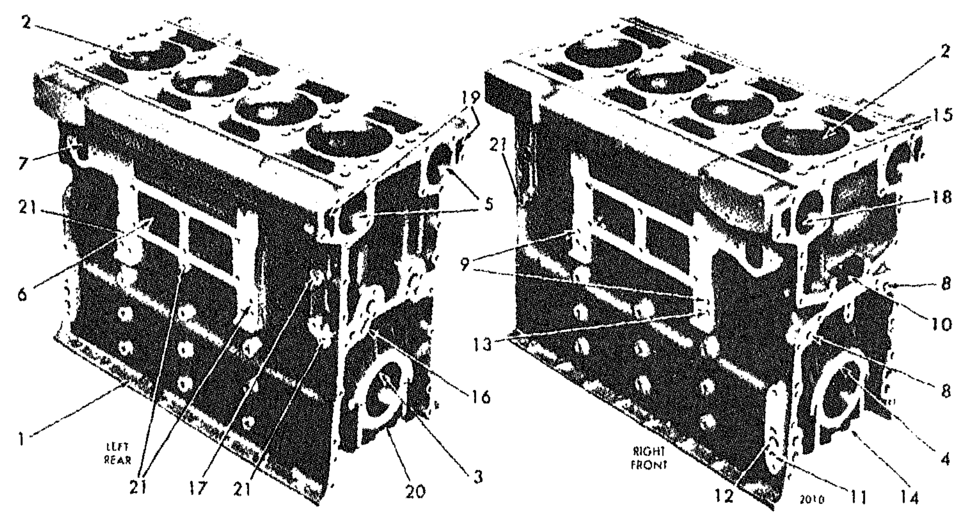
The water jacket and air box are sealed off by a seal ring compressed between the liner and a groove in the block (Fig . 3).

An air box surrounding the lower half of the cylinder liners conducts the air from the blower to the air inlet ports in the cylinder liners. An opening in the side of the block opposite the blower on the In-Line engines and air box openings in both sides of the block on the V-type engines provide access to the air box and permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners.

The camshaft and balance shaft bores are located on opposite sides near the top of the In-Line engine block.

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

The top surface of the In-Line block is grooved to accommodate a block-to-head oil seal ring. Also, each water or oil hole is counterbored to provide for individual seal rings (Fig. 6).



1. Cylinder Block
2. Bore for Cylinder Liner
3. Support--Upper Main Bearing (Rear)
4. Support--Upper Main Bearing (Front)
5. Bore--Cam or Balance Shaft
6. Air Box
7. Water Passage from Oil Cooler to Block
8. Oil Gallery (Main)
9. Oil Gallery (to Blower)
10. Oil Drain from Front Cover
11. Oil Passage to Oil Cooler
12. Oil Passage from Oil Cooler
13. Oil Drain from Blower
14. Cap--Main Bearing (Front)
15. Oil Passage to Cylinder Head (from Camshaft)
16. Oil Passage (Idler Gear Bearing)
17. Water Drain
18. Oil Gallery to Camshaft or Balance Shaft
19. Oil Drain from Cylinder Head
20. Cap--Main Bearing (Rear)
21. Oil Pressure Take-Off Opening

Fig. 1 - Cylinder Block (Four Cylinder Block Shown)

Each cylinder liner is retained in the block by a flange at its upper end, which seats in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

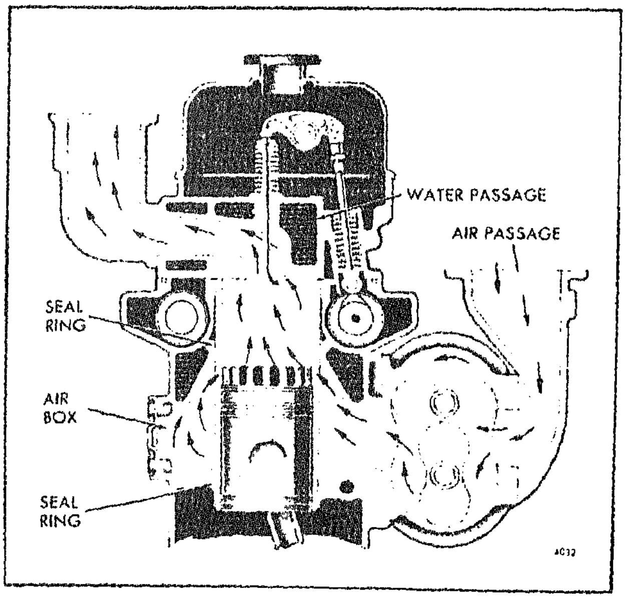


Fig. 3 · Air and Water Passages in In-Line Cylinder Block

When the cylinder head is installed, the gaskets and seal rings compress sufficiently to form a tight metal-to-metal contact between the head and the block.

The In-Line cylinder blocks were revised at the idler gear hub mounting pads, to increase the rigidity of the flywheel housing, by increasing two of the three 5/16" - 18 bolt holes of each mounting pad to 3/8" - 16 bolt holes (Fig. 7). The 3/8" - 16 bolt holes were incorporated in engines beginning with serial numbers 2D-903, 3D-011 and 4D-103. Revised end plates, end plate-to-block gaskets and flywheel housing are required with the change in bolt sizes. Only the revised cylinder blocks are available for service.

The In-Line cylinder blocks have also been revised to improve the breathing characteristics and increase the flow of the lubricating oil returning from the cylinder head to the engine oil sump by the addition of two vertical oil passages directly under the camshaft and balance shaft at the front end of the cylinder block (Fig. 8). Cylinder blocks with the vertical oil passages

were used in engines beginning with serial numbers 2D-4010, 3D-117 and 4D-348.

New service replacement cylinder block assemblies include the main bearing caps, bolts and washers and the camshaft bearings (bushings). The dowels and the necessary plugs are also included.

Since the cylinder block is the main structural part of the engine, the various sub-assemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Fig. 9) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 90 ° or 180 ° where it is locked in place and then, if desired, tipped back with either end or the oil pan side up.

Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the transmission or other driven mechanism. Details of this procedure will vary from one application to another. However, the following steps will be necessary:

1. Drain the cooling system.

2. Drain the lubricating oil.

3. Disconnect the fuel lines.

4. Remove the air silencer or air cleaner and mounting bracket.

5. Remove the turbocharger, if used.

6. Remove the blower on In-Line engines.

7. Disconnect the exhaust piping and remove the exhaust manifold(s).

8. Disconnect the throttle controls.

9. Disconnect and remove the starting motor, battery-charging generator and other electrical equipment.

10. Remove the air compressor, if used.

11. Remove the radiator and fan guard or the heat exchanger and other related cooling system parts.

12. Remove the air box drain tubes and fittings.

13. Remove the air box covers.

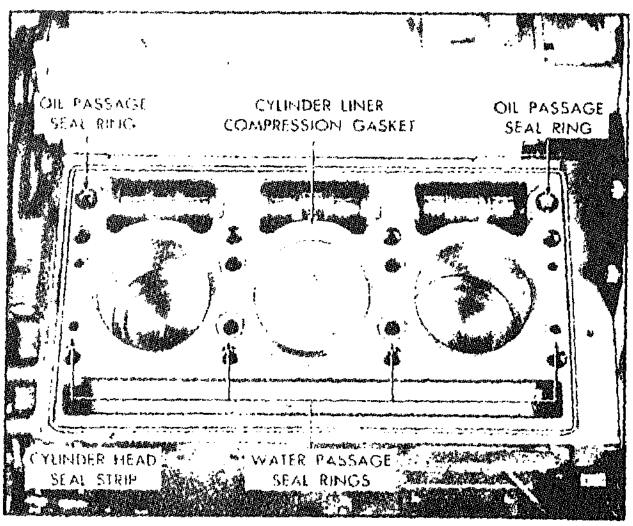


Fig. 6 · Cylinder Head Gaskets and Seals in Place on Cylinder Block

14. Disconnect any other lubricating oil lines, fuel lines or electrical connections.

15. Separate the engine from the transmission or other driven mechanism.

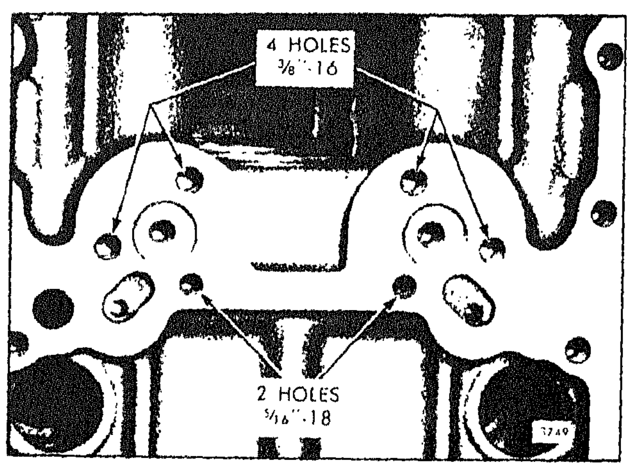


Fig. 7 · Location of the Four 3/8-16 Bolt Holes in Rear of Cylinder Block

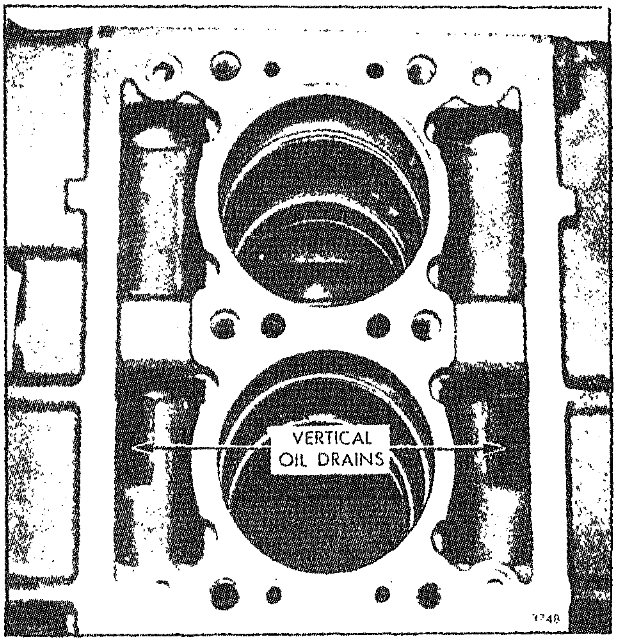


Fig. 8 - Vertical Oil Passages in Top of Cylinder Block

16. Remove the engine mounting bolts.

17. Use a chain hoist and suitable sling attached to the engine lifting brackets to lift the engine.

18. Place the side of the cylinder block against the adaptor plate on the overhaul stand (Fig. 9). Use adaptor plate J 7622 (In-Line engine), with overhaul stand J 6837-01.

19. Align the bolt holes in the adaptor plate with the holes in the cylinder block. Then install the 3/8 "-16 and 5/16 "-18 bolts, with a flat washer under the head of each bolt, and tighten them securely.

> **CAUTION:** Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the overhaul stand.

20. With the engine mounted on the overhaul stand, remove all of the remaining sub-assemblies and parts from the cylinder block.

The procedure for removing each sub-assembly from the cylinder block, together with disassembly, inspection, repair and reassembly of each, will be found in the various sections of this manual.

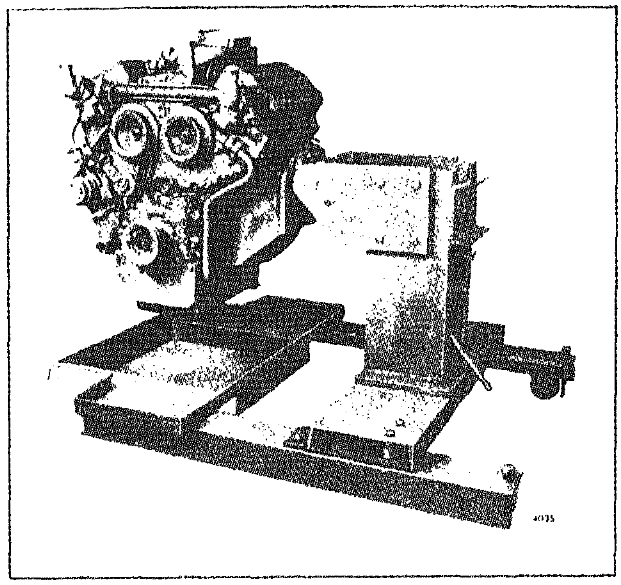


Fig. 9 - Engine Mounted on Overhaul Stand

After stripping, the cylinder block must be thoroughly cleaned and inspected.

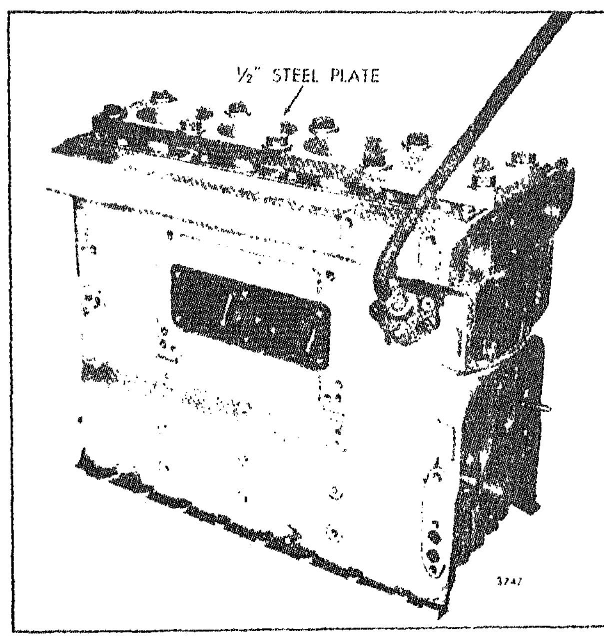


Fig. 10 - Cylinder Block Prepared for Pressure Test

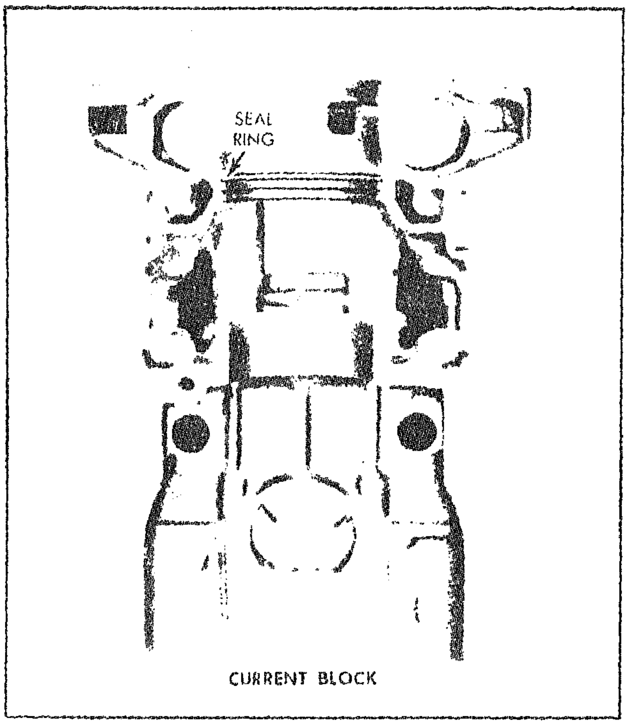


Fig. 11 - Location of Block Bore Seal Ring Groove

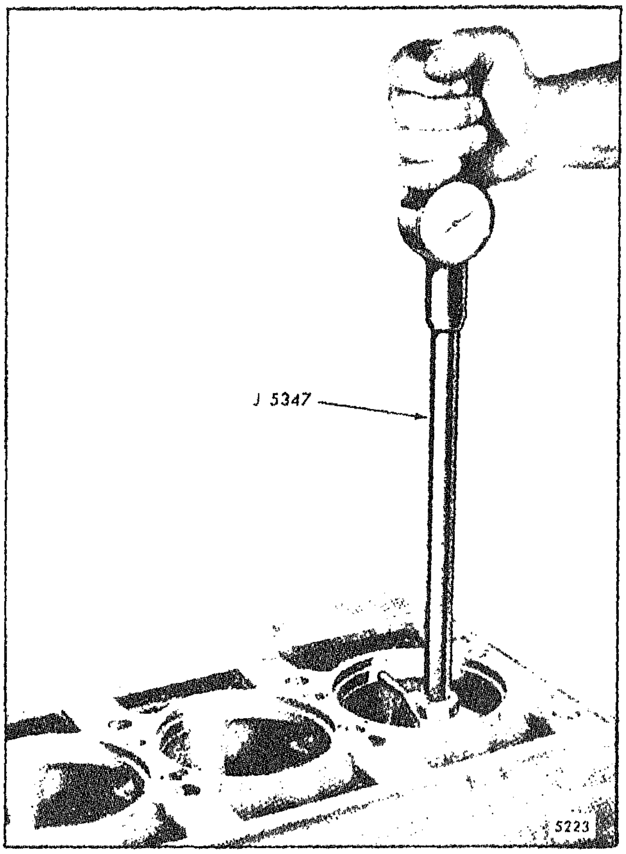


Fig. 12 - Checking Cylinder Block Bore with Tool J 5347

Clean Cylinder Block

1. Remove all of the plugs (except cup plugs) and scrape all old gasket material from the block.

2. Clean the block with live steam. Make sure the oil galleries, air box floor and air box drain openings are thoroughly cleaned.

Jets are not machined in the camshaft and balance shaft bushing bores in the current In-Line cylinder blocks. Oil is directed to the cam followers through small slots incorporated in the camshaft and balance shaft bearings.

3. Dry the block with compressed air.

Pressure Test Cylinder Block

After the cylinder block has been cleaned, it must be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make a steel plate of 1/2 " stock to cover each cylinder bank of the block (Fig. 10). The plate(s) will adequately seal the top surface of the block when used with cylinder liner compression gaskets and water hole seal rings. It will also be necessary to use water hole cover plates and gaskets to seal the water inlet openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line so the water jacket can be pressurized.

METHOD "A"

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

1. Make sure the seal ring grooves in the cylinder bores of the block are clean. Then install new seal rings in the grooves (above the air inlet ports).

> **NOTE:** The current blocks have two seal ring grooves above the air inlet ports of each cylinder bore. Only one seal ring is required, however. Install the seal ring in the upper groove, if it is in good condition; if the upper groove is pitted or eroded, install the seal ring in the lower groove.

2. Apply a light coating of hydrogenated vegetable

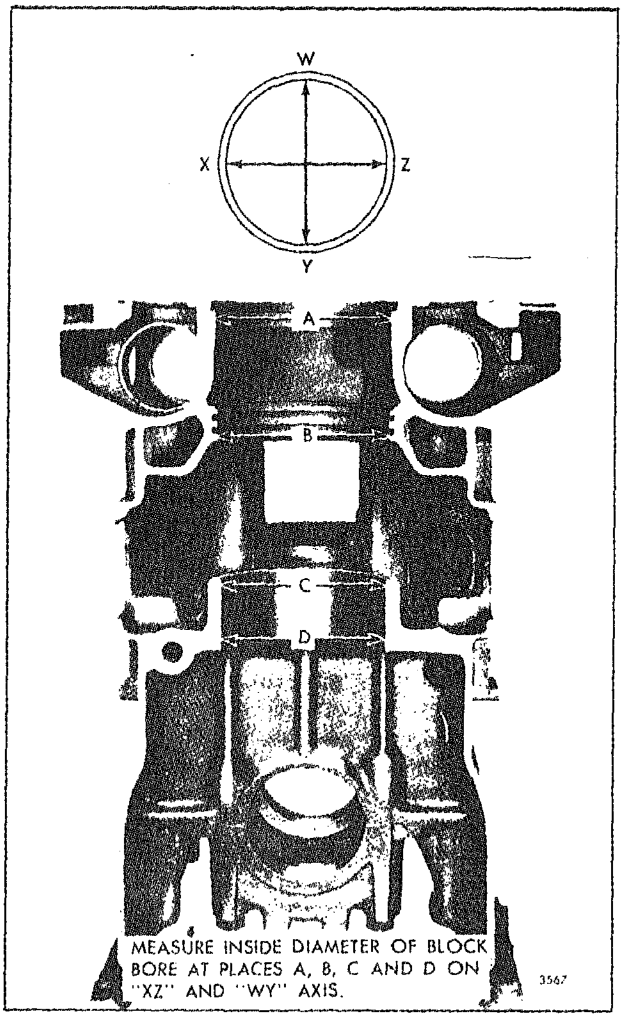


Fig. 13 - Block Bore Measurement Diagram

type shortening or permanent type antifreeze solution to the seal rings.

3. Slide the cylinder liners into the block, being careful not to roll or damage the seal rings. Install new compression gaskets and water hole seal rings in the counterbores in the top surface of the block.

4. Secure the plate(s) on the top of the block with 5/8 "-11 bolts and flat washers.

5. Install the water hole cover plates and gaskets on the sides of the block.

6. Immerse the cylinder block for twenty minutes in a tank of water heated to 180 ° - 200 ° F.

7. Attach an air line to the water hole cover plate and apply 60 psi air pressure to the water jackets and observe the water in the tank for bubbles which will

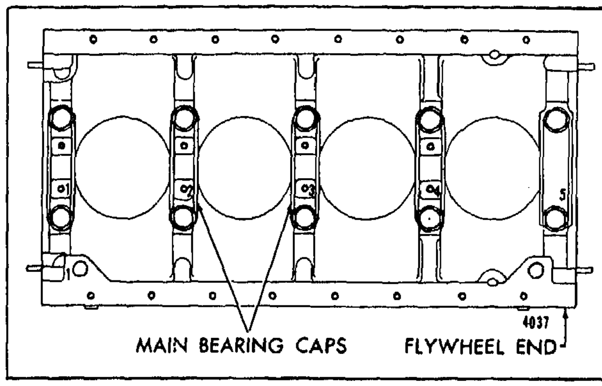


Fig. 14 - Typical Cylinder Block Markings

indicate cracks or leaks. A cracked cylinder block must be replaced by a new block.

8. Remove the block from the water tank. Then remove the plates, seals, gaskets and liners and blow out all of the passages in the block with compressed air.

9. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

METHOD "B"

This method may be used when a large water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove the cylinder head(s), blower, oil cooler, air box covers and oil pan.

1. Prepare the block as outlined in Method "A". However, before installing the large sealing plate, fill the water jacket with a mixture of water and one gallon of permanent type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.

2. Install the plate(s) and water hole covers as outlined in Method "A".

3. Apply 60 psi air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.

4. At the end of this test period, examine the cylinder bores, air box, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture which will indicate the presence of cracks. A cracked cylinder block must be replaced by a new block.

5. After the pressure test is completed, remove the

plates and drain the water jacket. Then remove the liners and seal rings and blow out all of the passages in the block with compressed air.

6. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

1. Check the block bores as follows:

a. Make sure the seal ring grooves (Fig. 11) are thoroughly clean. Then inspect the grooves and lands for evidence of pitting and erosion. Two grooves are provided above the air inlet ports of each cylinder bore in the current block. The single groove formerly below the air inlet ports has been eliminated. However, a cylinder liner seal ring is required in the upper groove only. The lower groove (on the current block) is provided for the seal ring if inspection reveals extensive pitting or erosion along the upper land or inner surface of the upper groove. If both grooves are eroded to the extent that sealing is affected, then the block must be replaced.

b. Measure the entire bore of each cylinder with cylinder bore gage J 5347 (Fig. 12) which has a dial indicator calibrated in .0001 " increments. Use dial bore gage setting tool J 23059 to preset the cylinder bore gage to zero. Measure each block bore at the positions indicated in Fig. 13, on axis 90 ° apart. If the diameter does not exceed 4.5235 " at position "A", 4.4900 " at position "B" (and a sealing problem hasn't occured), or 4.3595 " at position "C" and "D", then the block may be reused. Also, the taper and out of round must not exceed .0015 ".

2. Check the top of the block for flatness with an accurate straight edge and a feeler gage. The top surface must not vary more than .003 " transversely and not over .006 " (3-53 engine) longitudinally.

3. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth. The depth must be .300 " to .302 " and must not vary more than .0015 " throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within .001 " total indicator reading. There must not be over .001 " difference between any two adjacent cylinder counterbores, when measured along the cylinder longitudinal centerline of the cylinder block.

4. Check the main bearing bores as follows:

a. Check the bore diameters with the main bearing caps in their original positions. Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Then install and tighten the bolts to the specified torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 3.251 " to 3.252 " (In-Line engine). If the bores do not fall within these limits, the cylinder block must be rejected.

CAUTION: Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. Effective with engine serial numbers 6D-27030 and 8D-1155, a new hexagon head bolt and hardened steel washer are being used in place of the former 12-point flange type main bearing cap bolt.

NOTE: Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is also stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 14).

b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a *finished* replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap.

NOTE: Use the unfinished bearing caps for the front and intermediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

c. Main bearing bores are line-bored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened to the specified torque. If a main bearing bore is more

than .001 " out of alignment, the block must be line-bored or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

d. If the main bearing bores are not in alignment or a replacement bearing cap is used, the block must be line-bored. Install the bearing caps in their original positions (without the bearing cap stabilizers) and tighten the bolts to the specified torque (Section 1.0). Line-bore the block, but do not remove more than .001 " stock. After boring, all bores must be within the specified limits of 3.251 " to 3.252 " (In-Line block).

5. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .680 " from the cylinder block face.

The dowels used to retain the crankshaft thrust washers on the rear main bearing cap must extend .107" to .117" from the surface of the bearing cap.

6. Check all of the machined surfaces and threaded holes in the block. Remove nicks and burrs from the machined surfaces with a file. Clean-up damaged threads in tapped holes with a tap or install helical thread inserts.

7. After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time, spray or dip it in a polar type rust preventive such as Valvoline Oil Company's "Tectyl 502-C", or equivalent. Castings free of grease or oil will rust when exposed to the atmosphere.

Assemble and Install Engine

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

NOTE: Before a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.

1. Mount the block on the overhaul stand.

2. If a new service replacement block is used, stamp the engine serial number and model number on the upper rear corner of the In-Line block. Also stamp the position numbers on the main bearing caps (Fig. 14) and the position of the No. 1 bearing on the oil pan mounting flange of the block.

3. Install all of the required plugs and drain cocks. Use a good grade of sealing compound on the threads of the plugs and drain cocks. If a new service replacement block is used, make sure the top surface is plugged correctly to prevent low oil pressure or the accumulation of abnormal quantities of oil in the cylinder head.

4. Clean and inspect all of the engine parts and sub-assemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and sub-assemblies are outlined in the following sections of this manual.

5. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.

6. Install the air box covers and tighten the bolts. On In-Line engines, tighten the bolts to 12-16 lb-ft torque.

7. Complete the engine build-up by installing all remaining accessories, fuel lines, electrical connections, controls etc.

8. Operate the engine on a dynamometer, following the RUN-IN procedure outlined in Section 13.2.1.

9. Reinstall the engine in the equipment which it powers.

CYLINDER BLOCK END PLATE

A flat steel plate, bolted to the rear end of the cylinder block, provides a support for the flywheel housing. A gasket is used between the block and the end plate.

Inspection

When the end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the end plate and the cylinder block. Clean the end plate as outlined under *Clean Cylinder Block* in Section 1.1.

Inspect both surfaces of the end plate for nicks, dents, scratches or score marks and check it for warpage. Check the plug nuts in the end plate for cracks or damaged threads. If nicks or scratches on the sealing surfaces of the end plate are too deep to be cleaned up, or the plug nuts are damaged, replace the end plate or plug nuts.

When installing a plug nut, support the end plate on a solid flat surface to avoid distorting the plate. Then press the nut in the end plate until the head on the nut seats on the end plate.

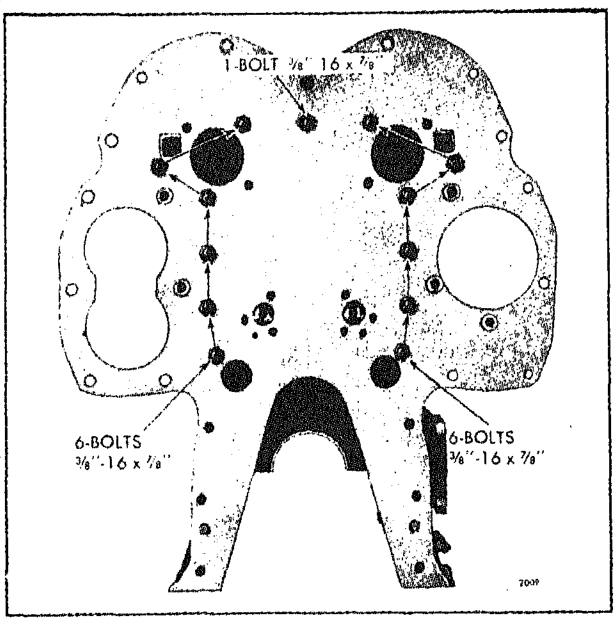


Fig. 1 - Cylinder Block Rear End Plate Mounting (In-Line Engine)

Install End Plate

1. Affix a new gasket to the end of the cylinder block (flywheel end), using a non-hardening gasket cement. Also apply an even coating of gasket cement to the outer surface of the gasket (the surface next to the end plate).

2. Align the dowel pin holes in the end plate with the dowel pins in the cylinder block. Then start the end plate over the dowel pins and push it up against the cylinder block.

> **NOTE:** When installing the end plate, the heads of the plug nuts at the top of the end plate on the In-line engine
>
> should always face the forward end of the cylinder block.

3. On In-line engines, refer to Fig. 1 and install the 3/8 ″-16 x 7/8 ″ bolts with lock washers. Tighten the bolts to 30-35 lb-ft torque.

NOTE: On In-line engines built prior to engine serial numbers 2D-903, 3D-011 and 4D-103, the top center end plate attaching bolt was 3/8 ″-16 x 3/4 ″. Do not use a longer bolt at this location on engines built prior to the above engine serial numbers.

4. On a V-type engine, refer to Fig. 2 for the location and install the 3/8 ″-16 x 1 ″ bolts with lock washers. Also install the two special washers and two 1/2 ″-13 x 1-1/2 ″ bolts as shown when the fuel pump is driven off the camshaft, or one special washer and bolt when the fuel pump is driven by the accessory gear. Tighten the 3/8 ″-16 bolts to 30-35 lb-ft torque and the 1/2 ″-13 bolts to 71-75 lb-ft torque.

AIR BOX DRAINS

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condenses and settles on the bottom of the air box. This condensation is removed by the air box pressure through air box drain tubes mounted on the sides of the cylinder block.

The air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

One drain tube is used on an In-line engine (Fig. 1).

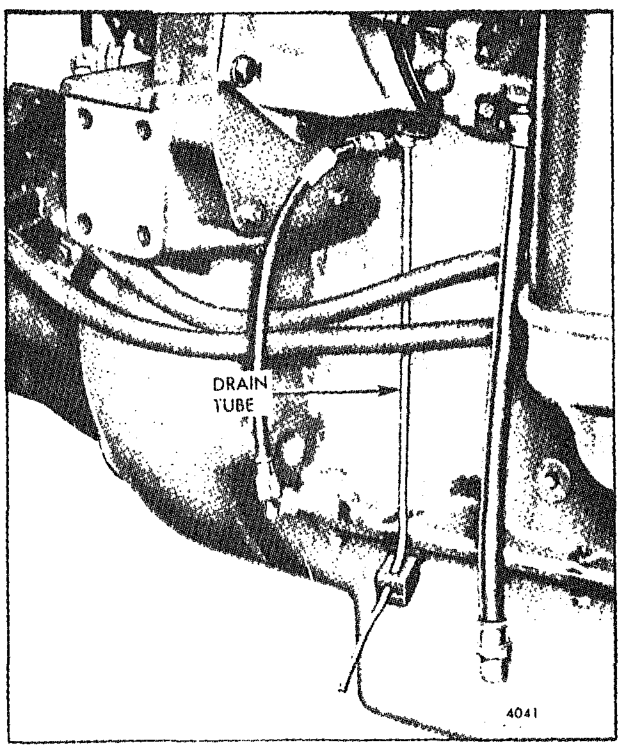


Fig. 1 - Air Box Drain Tube Mounting (In-Line Engines)

Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Section 15.1).

CYLINDER HEAD

The cylinder head (Fig. 1) is a one-piece casting. It may be removed from the engine as an assembly containing the cam followers, cam follower guides, rocker arms, exhaust valves and injectors. The head is securely held to the top of the cylinder block with bolts.

Located in the cylinder head are the exhaust valves, a fuel injector and three rocker arms for each cylinder. One rocker arm operates the injector plunger; the other two operate the exhaust valves. The rocker arms are operated by a camshaft through cam followers and push rods.

Exhaust valve inserts (valve seats), pressed into the cylinder head, permit accurate seating of the valves under varying conditions of temperature and materially prolong the life of the cylinder head. The inserts are ground to very close limits and their freedom from

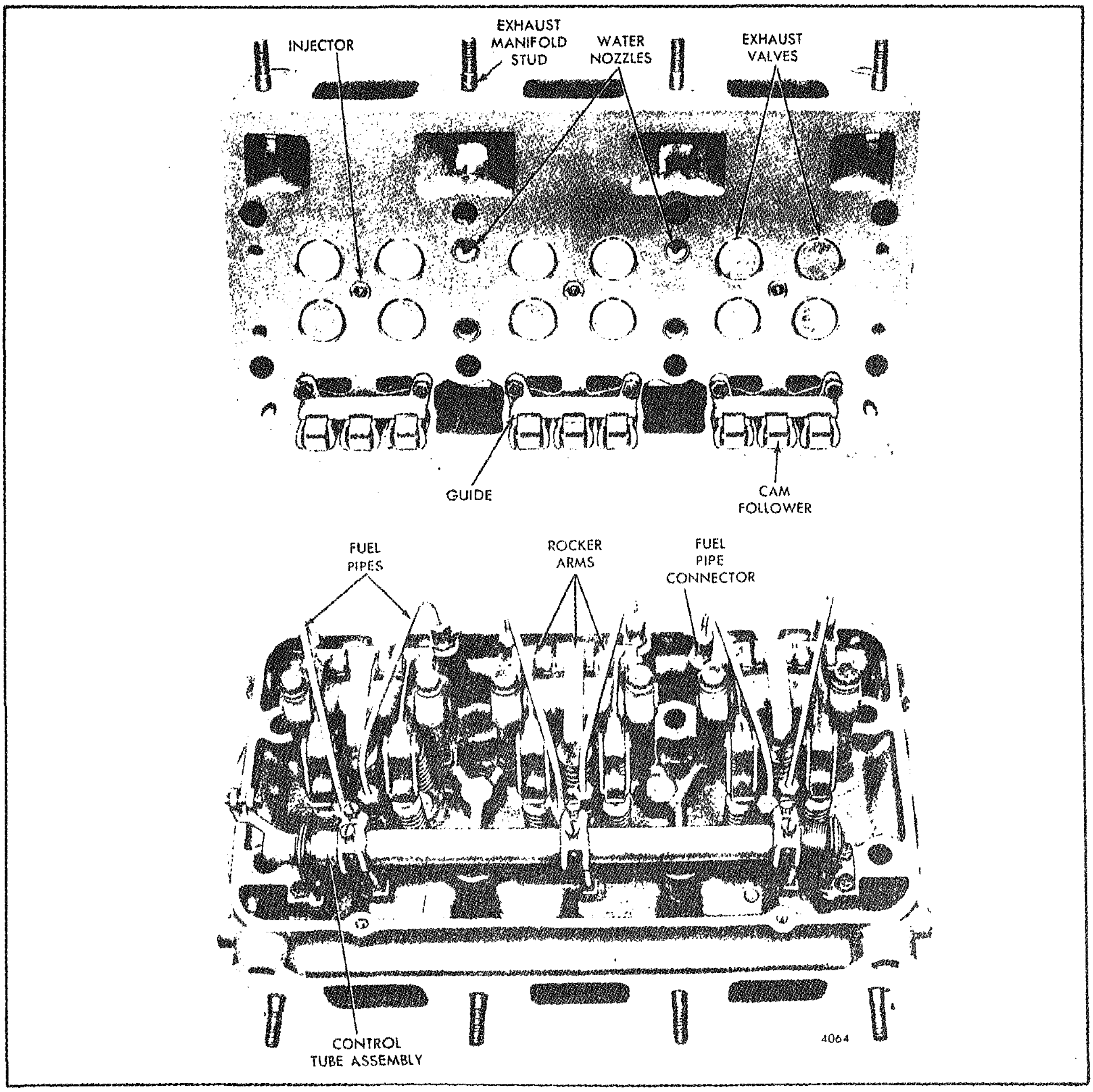


Fig. 1 - Typical Four-Valve Cylinder Head Assembly

'arpage, under ordinary conditions, reduces valve :econditioning to a minimum.

'o ensure efficient cooling, each fuel injector is iserted into a thin-walled tube which passes through ie water space in the cylinder head. The lower end of ie injector tube is pressed into the cylinder head and ared over; the upper end is flanged and sealed with a eoprene seal. The flared lower end and sealed upper nd prevent water leaks around the copper tube.

'he exhaust passages from the exhaust valves of each ylinder lead through a single port to the exhaust ianifold. The exhaust passages, exhaust valve inserts nd injector tubes are completely surrounded by ooling system water.

1 addition to being surrounded by water, cooling of iese areas is further assured by the use of double jet pray nozzles installed between each pair of cylinders 1 the water inlet ports of four valve cylinder heads. Jozzle holes are so positioned in the cylinder head iat the comparatively cool water which enters the ead is directed at high velocity against the sections of ie head which are subjected to the greatest heat.

o seal compression between the cylinder head and ie cylinder liner, separate laminated metal gaskets :e provided at each cylinder. Water and oil passages etween the block and head are sealed with synthetic ibber seal rings which fit into counterbored holes in ie block. A synthetic rubber seal fits into a milled roove in the block near the outer edge of the area overed by the cylinder head. When the cylinder head pulled down, a positive leakproof metal-to-metal ontact is assured between the head and block.

ertain service operations on the engine require the :moval of the cylinder head. These operations are:

. Removing and installing the pistons.

. Removing and installing the cylinder liners.

. Removing and installing the exhaust valves.

. Removing and installing the valve guides.

Reconditioning the exhaust valves and valve seats.

Replacing the injector tubes.

Installing new cylinder head gaskets.

Removing and installing a camshaft.

Cylinder Head Maintenance

Engine temperatures should be maintained between 160° and 185°F. and the cooling system should be inspected daily and kept full at all times.

Unsuitable water in the cooling system may result in lime and scale formation which prevent proper cooling. The cylinder head should be inspected around the exhaust valve water jackets. This can be done by removing an injector tube. Where inspection discloses such deposits, a reliable non-corrosive scale remover should be used to remove the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine. Refer to Section 13.3 for engine coolant recommendations.

Adding cold water to a hot engine may result in head cracks. Water must be added slowly to a hot engine to avoid rapid cooling which will result in distortion and cracking of the cylinder head (and cylinder block).

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and cause a loss of engine coolant. The tubes should be tight and properly seated. Refer to Section 2.1.4.

The development of cracks in the cylinder head may be caused by abnormal operating conditions or through neglect of certain maintenance items. If this type of failure should occur, a careful inspection should be made to determine the cause so that a recurrence of the failure will be prevented.

Overtightening the injector clamp bolts may also result in head cracks. Always use a torque wrench to tighten the bolts to the specified torque.

Other conditions which may eventually result in head cracks are:

1. Excess fuel in the cylinders due to leaking injectors.

2. Oil pull-over due to an overfilled air cleaner sump, or improper viscosity oil in the air cleaner.

3. Neglected cylinder block air box drains which allow accumulated oil to be drawn into the cylinders.

Remove Cylinder Head

Due to various optional and accessory equipment used on the different engine models, only the general steps for removal of the cylinder head are covered. If the engine is equipped with special accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to assure the correct reinstallation.

1. Disconnect the exhaust piping at the exhaust manifold.

2. Drain the cooling system.

3. Remove the air cleaner(s) or air silencer.

4. Disconnect the fuel lines at the cylinder head.

5. Remove the thermostat housing and the thermostat as an assembly.

6. Clean and remove the valve rocker cover.

7. Disconnect and remove the fuel rod between the governor and the injector control tube lever. Remove the fuel rod cover, if used.

8. Remove the exhaust manifold.

9. Remove the injector control tube and brackets as an assembly.

10. If the cylinder head is to be stripped for reconditioning of valves and valve seats or for a complete cylinder head overhaul, remove the fuel pipes and injectors at this time. Refer to Sections 2.1 or 2.1.1 for removal of the injectors.

11. Remove the cylinder head bolts. Then, lift the cylinder head off of the cylinder block, with lifter tool J 22062-01 (Fig. 2).

> **CAUTION:** When resting the cylinder head assembly on a bench, protect the cam follower rollers and the injector spray tips by resting the valve side of the head on 2" thick wood blocks.

12. Remove the cylinder head compression gaskets, oil seals and water seals.

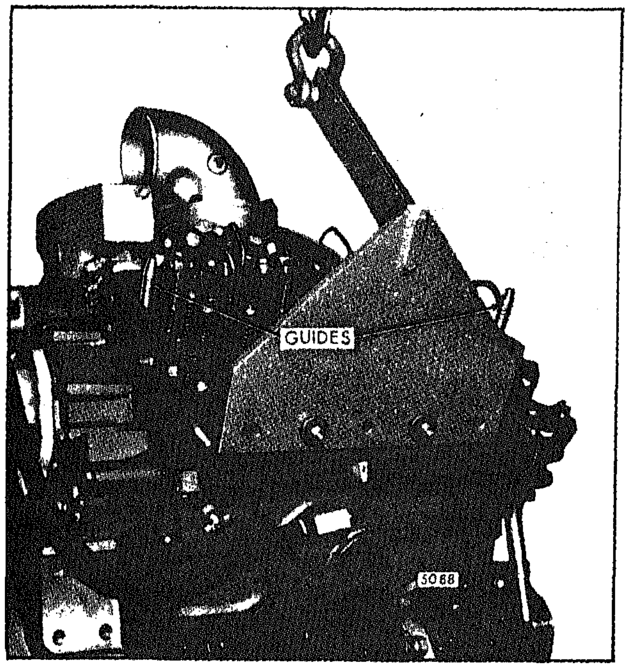


Fig. 2 - Lifting Cylinder Head Assembly Off Cylinder Block with Tool J 22062-01

The removal procedures to be followed, when removing the parts mentioned above, are covered in their respective sections of this manual.

Disassemble Cylinder Head

If a cylinder head is removed for inspection and possible repair or replacement, remove the following parts:

1. Fuel injectors, if not previously removed.

2. Fuel connectors.

3. Cam follower guides and cam followers.

4. Rocker arms, rocker arm shafts, brackets, push rods, push rod springs, spring seats and spring seat retainers.

5. Exhaust valves and valve springs.

Clean Cylinder Head

After the cylinder head has been stripped of all the component parts and all of the plugs (except cup plugs) have been removed, steam clean the head thoroughly.

Thoroughly clean a new service cylinder head to remove all of the rust preventive compound, particularly from the integral fuel manifolds, before the plugs are installed in the fuel manifolds and the head is mounted on the engine. A simple method of removing the rust preventive compound is to immerse the head in solvent, oleum or fuel oil; then, go over the head and through all of the openings with a soft bristle brush. A suitable brush for cleaning the fuel manifolds can be made by attaching a 1/8" brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

Inspect Cylinder Head

1. Check the cylinder head for leaks as follows:

a. Seal off the water holes in the head with steel plates and suitable rubber gaskets held in place by bolts.

1.2 Cylinder Head

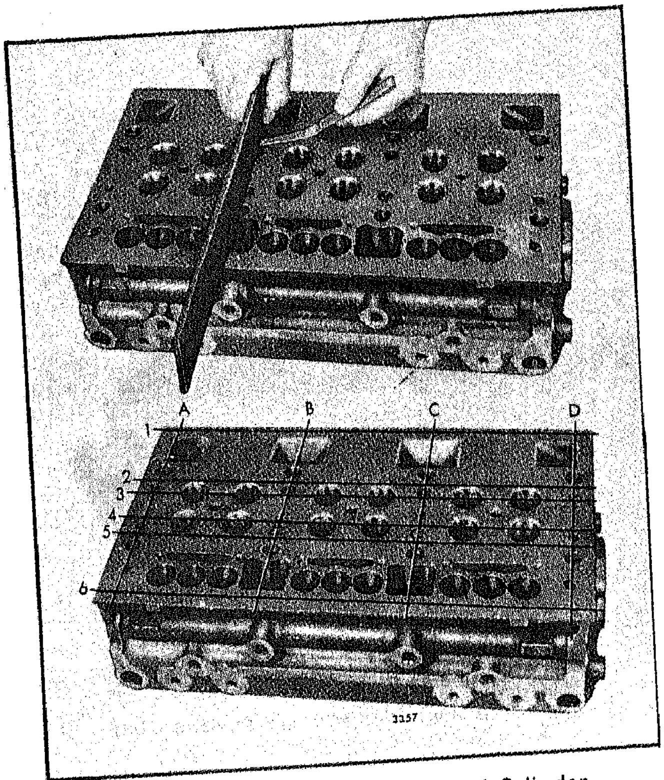


Fig. 3 - Checking Bottom Face of Cylinder Head for Warpage

b. Install dummy or scrap injectors to ensure seating of the injector tubes. Dummy injectors may be made from old injector nuts and bodies - the injector spray tips are not necessary. Tighten the injector clamp bolts to 20-25 lb-ft torque.

c. Drill and tap into one of the water hole cover plates for an air hose connection and apply 80-100 psi air pressure to the water jacket. Then, immerse the head in a tank of water previously heated to 180-200°F. for twenty minutes to thoroughly heat the cylinder head. Observe the water in the tank for bubbles indicating cracks or leaks.

d. Remove the cylinder head from the tank and dry it with compressed air.

e. If inspection revealed cracks, replace the cylinder head.

f. Replace any leaking injector tubes as outlined in Section 2.1.4.

Over a prolonged period of operation, the cylinder head may assume a contour to match that of the cylinder block, which is normal. However, if the cylinder head is allowed to become overheated because of coolant loss, the resultant high temperatures cause stresses to occur in the casting which will affect the flatness of the head.

2. Check the bottom (fire deck) of the cylinder head for flatness as follows:

a. Use an accurate straightedge and feeler gage J 3172 to check for transverse warpage at each end and between all of the cylinders. Also, check for longitudinal warpage in six places as shown in Fig. 3. Maximum allowable warpage is given in the following chart:

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
3-53	.005"	.004"

b. The maximum allowable warpage limits should be used as a guide in determining the advisability of reinstalling the head on the engine or of refacing it. The number of times a cylinder head may be refaced will, of course, depend upon the amount of stock removed from the head during previous reworking operations.

c. If the cylinder head is to be refaced, remove the injector tubes prior to machining. Not over .020" of metal should be removed from the fire deck of the cylinder head. The distance from the top to the bottom (fire deck) of the cylinder head must not be less than 4.376", as shown in (Fig. 4). Stamp the amount of stock removed on the face of the fire deck near the outer edge of the head, in an area not used as a sealing surface.

d. After a cylinder head has been refaced and new injector tubes have been installed as outlined in Section 2.1.4, pressure check the cylinder head as outlined in Step 1.

3. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned

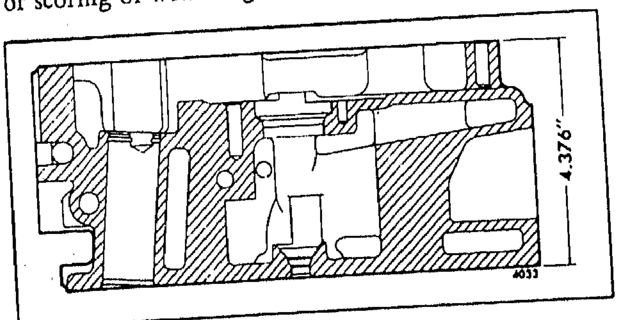


Fig. 4 - Minimum Distance Between Top and Bottom Faces of Cylinder Head

up with crocus cloth wet with fuel oil. If the bores are excessively scored or worn so that the cam follower-to-head clearance exceeds .006", replace the cylinder head.

4. Inspect the valve seat inserts for cracks or burning. Also, check the valve guides for scoring.

5. Check the water nozzles in a four-valve cylinder head to be sure they are not loose. Water nozzles are used only in the passages between the cylinders. If necessary, install or replace the water nozzles as follows:

a. Be sure the water inlet ports in the bottom of the head are clean and free of scale. The water holes may be cleaned up with a 5/8" diameter drill. Break the edges of the holes slightly.

b. If the water holes in the head have been enlarged by corrosion, use a wooden plug or other suitable tool to expand the nozzles so that they will remain tight after installation.

c. Press the nozzles in place with the outlet holes positioned as shown in Fig. 5. The angle between the outlet holes in the nozzle is 90°. Press the nozzles from flush to 1/32" below the bottom surface of the cylinder head.

6. Inspect the parts removed from the cylinder head before they are reinstalled in the old head or transferred to a new cylinder head.

Assemble Cylinder Head

New service cylinder heads include valve guides, valve seat inserts, water nozzles, injector tubes and the necessary plugs.

> **CAUTION:** When installing the plugs in the fuel manifolds, apply a small amount of sealant merchandized as a "dual purpose sealer" to the threads of the plugs only. Work the sealant into the threads and wipe off the excess with a clean, lint-free cloth so that the sealant will not be washed into the fuel system and result in damage to the injectors.

When a new cylinder head is to be used, remove the parts listed below from the old head and install them in the new head. If the old cylinder head is to be reused, install the parts in the old head prior to assembling the head on the cylinder block.

1. Exhaust manifold studs.

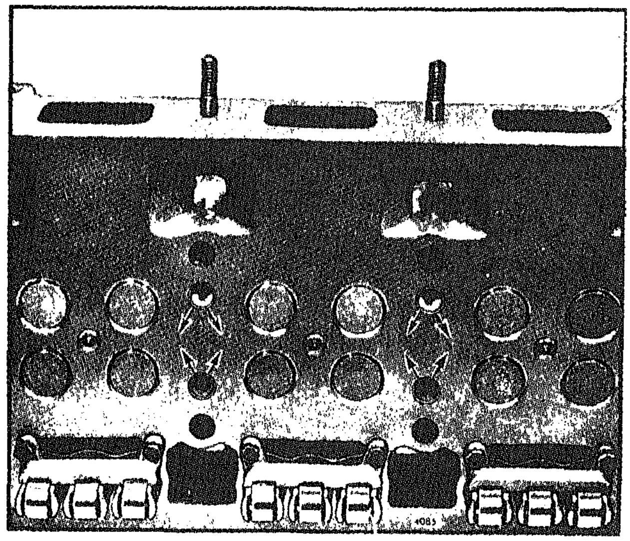


Fig. 5 - Correct Installation of Water Nozzles in Four-Valve Cylinder Head

2. Exhaust valves and springs (Section 1.2.2).

3. Install the fuel injectors at this time or after installing the cylinder head (Sections 2.1 or 2.1.1).

4. Cam followers, cam follower guides, push rod assemblies, rocker arm shafts and rocker arms; do not tighten the rocker arm bracket bolts at this time (Section 1.2.1).

5. Place new washers on the fuel connectors, then install the fuel connectors and tighten them to 20-28 lb-ft torque.

Pre-Installation Inspection

Perform the following inspections just prior to installing the cylinder head on the engine.

1. Check the cylinder liner flange height as outlined in Section 1.6.3.

2. Check to be sure the tops of the pistons are clean and free of foreign material.

3. Check to see that each push rod is threaded into the clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is rotated during tune-up.

4. Check to be sure that the groove and the counterbores in the top of the cylinder block are clean and smooth.

1.2 Cylinder Head

Install Cylinder Head

1. Install new cylinder head compression gaskets and seals as outlined below:

   a. Place a new compression gasket on each cylinder liner.

   b. Place new seal rings in the counterbores of the water and oil holes in the cylinder block.

   c. Install a new oil seal in the milled groove in the cylinder block near the outer edge of the area covered by the cylinder head.

   NOTE: Used water seals, oil seals and compression gaskets should *never* be used.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, use guide stud set J 9665. Install the guide studs in the end cylinder block bolt holes (Fig. 2).

3. Make a final visual check of all of the cylinder head gaskets and seals to ensure that they are in place just before the cylinder head is lowered onto the cylinder block. *This is a very important check.* Compression gaskets and seals which are jarred out of their proper position will lead to leaks and "blow-by" with resultant poor engine performance and damage to the engine.

4. Wipe the bottom of the cylinder head clean; then, lower the head on the block.

5. Lubricate the threads and the underside of each cylinder head bolt with a small quantity of International Compound No. 2, or equivalent. Then, install the bolts. On the In-line engines equipped with both six and twelve point cylinder head bolts, the twelve point bolts must be installed on the camshaft side of the head to eliminate possible interference between the governor control link and the cylinder head bolt.

   NOTE: Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

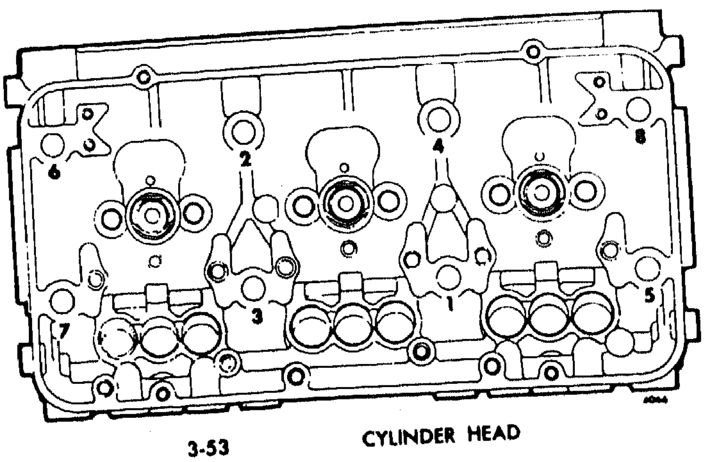


Fig. 6 - Sequence for Tightening Cylinder Head Bolts

6. The cylinder head must be gradually and uniformly drawn down against the gaskets and seals to ensure a good seal between the cylinder head and the block. Therefore, it is vitally important that the cylinder head be installed with the utmost care.

7. Then, begin on the camshaft side of the head to take up the tension in the cam follower springs by tightening the bolts lightly. Finally tighten the bolts to 170-180 lb-ft torque with a torque wrench, about one-half turn at a time, in the sequence shown in Fig. 6. Under no circumstances should the torque exceed the specified limits, otherwise the bolts may become stretched beyond their elastic limits.

8. Cover the oil drain holes in the cylinder head to prevent foreign objects from falling into the holes.

9. If the injectors were not previously installed, refer to Section 2.1 or 2.1.1 and install them at this time.

10. Tighten the rocker arm bracket bolts to 50-55 lb-ft torque.

> **CAUTION:** There is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker arm bracket bolts. Therefore, note the position of the exhaust valve bridge before, during and after tightening the bolts.

11. Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb-ft torque.

> **CAUTION:** Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

12. Set the injector control tube assembly in place on the cylinder head and tighten the bolts, finger tight only. When positioning the injector control tube, be sure that the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10-12 lb-ft torque.

13. After tightening the bolts, revolve the tube and see if the return spring pulls the injector racks out (no-fuel position) after they have been moved all the way in (full-fuel position). Since the injector control tube is mounted in self-aligning bearings, tapping the tube lightly with a soft hammer will remove any bind that exists. The injector racks *must* return to the no-fuel position freely by aid of the return spring only. *Do not* bend the return spring to bring about this condition.

14. Install the fuel rod and the fuel rod cover (if used).

15. Remove the covers from the drain holes in the head.

16. Install the exhaust manifold and connect the exhaust piping.

17. Install the thermostat housing and the thermostat.

18. Install the air cleaners.

19. Connect the fuel lines.

20. Fill the cooling system and check for leaks.

21. With the throttle in the OFF position, crank the engine over to be sure that all of the parts function freely.

22. Before starting the engine, perform an engine tune-up as outlined in Section 14.

23. Refer to Section 13.1 and start the engine. After starting the engine, check all fuel line connections to ensure that no fuel oil leaks into the cylinder head compartment to dilute the lubricating oil.

24. After the engine has been warmed up (to at least 160°F.), recheck the torque on the cylinder head bolts.

25. Recheck the exhaust valve clearance and the injector timing after the engine reaches normal operating temperature.

26. Examine all fuel oil, lubricating oil and water connections for possible leaks. Tighten the connections, if necessary.

27. Install the valve rocker cover, using a new gasket.

VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of rocker arm assemblies pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Consequently, the removal of two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and valve springs.

The rocker arms are operated by the camshaft through cam followers and short push rods extending through the cylinder head (Fig. 1).

Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to keep the follower rollers in line with the cams and serves as a retainer during assembly and disassembly.

A coil spring, located inside of each cam follower, is held in place in the cylinder head by a spring seat and spring seat retainer.

Several operations may be performed on the valve mechanism without removing the cylinder head from the cylinder block, while the head must be removed for certain other operations. The operations NOT requiring removal of the cylinder head are:

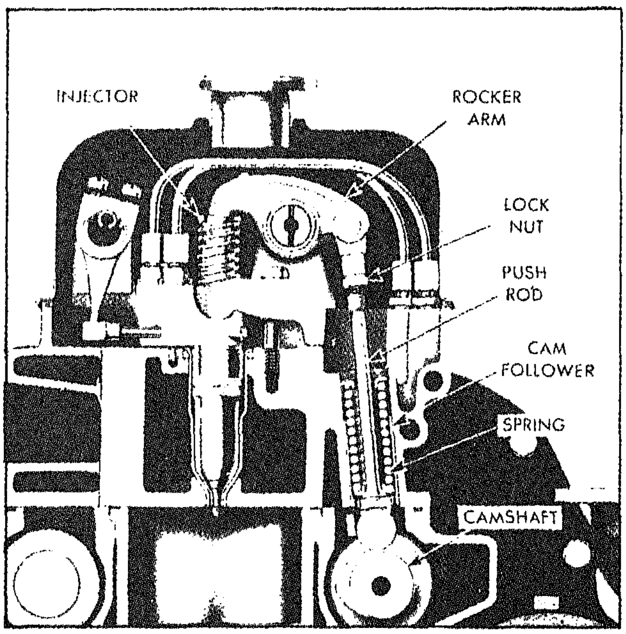


Fig. 1 - Injector Operating Mechanism (In-Line Engine Shown)

1. Adjusting valve clearance.
2. Removing and installing a valve spring.
3. Removing and installing a rocker arm.
4. Removing and installing a rocker arm shaft or shaft bracket.
5. Removing and installing an injector.

It is also possible, if occasion requires, to remove or replace a push rod, push rod spring, spring seats or cam follower without removing the cylinder head. These parts, however, are more easily changed from the lower side of the cylinder head when the head is off the engine. Both methods are covered in this Section.

To remove and install valves, valve guides, valve seat inserts and to recondition valves and valve seats, the cylinder head must be removed. Exhaust valves, guides and inserts are covered in Section 1.2.2.

Lubrication

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage, on the camshaft side of the cylinder head, which connects with oil passages in the cylinder block. Oil from this

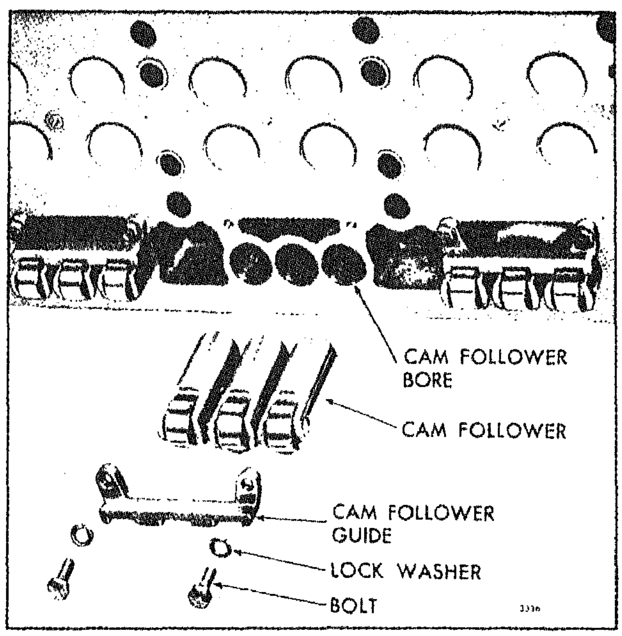


Fig. 2 - Cam Follower and Guide Location

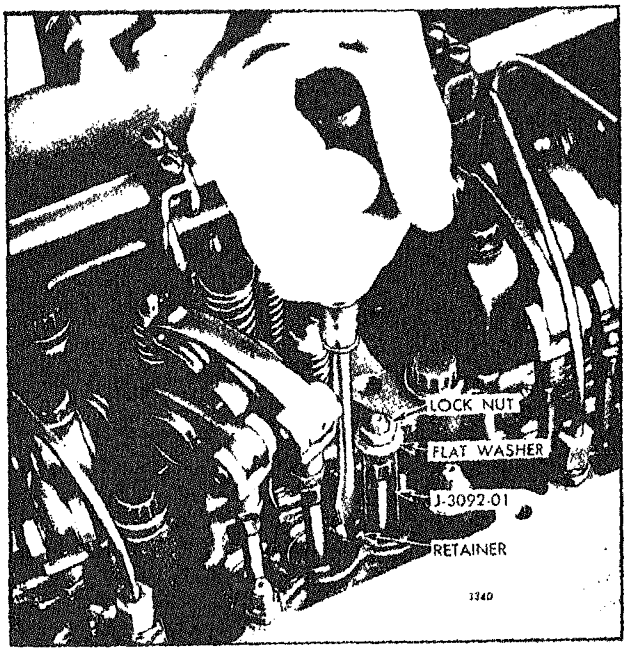


Fig. 3 · Removing Push Rod from Upper Side of Cylinder Head with Tool J 3092-01

longitudinal passage enters the drilled rocker arm shafts through the lower end of the drilled rocker shaft bracket bolts and lubricates the rocker arms.

Excess oil from the rocker arms lubricates the exhaust valves and cam followers. Additional cam follower lubrication is provided by oil from grooves in the camshaft bushing bores which is directed against the cam follower rollers.

Remove Rocker Arms and Rocker Arm Shaft

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from the injector and the fuel connectors.

> **CAUTION:** Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

3. Bar the engine over in the direction of engine rotation or crank the engine with the starting motor to bring the push rod ends -- the outer ends -- of the injector and valve rocker arms in line horizontally.

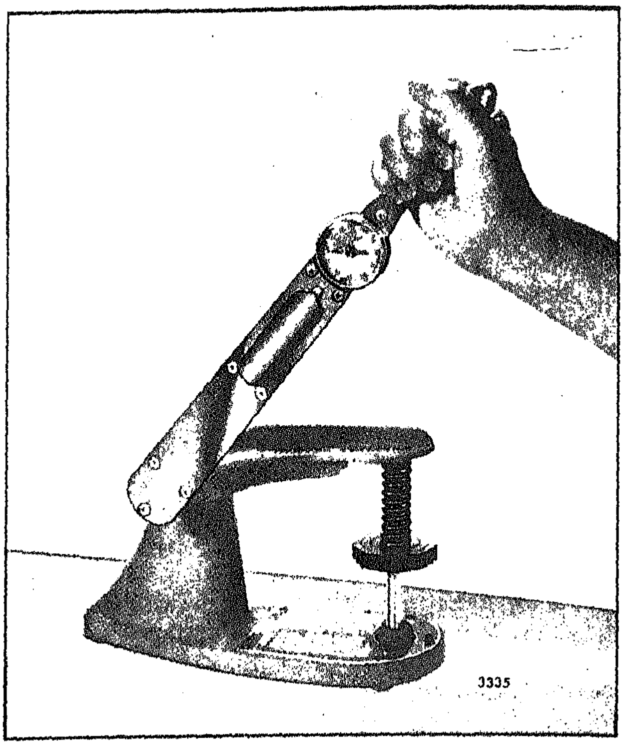


Fig. 4 · Testing Push Rod Spring

4. Remove the two bolts which hold the rocker arm shaft brackets to the cylinder head. Remove the brackets and the shaft.

5. Loosen the lock nut at the upper end of the push rod, next to the clevis, and unscrew the rocker arm from the push rod.

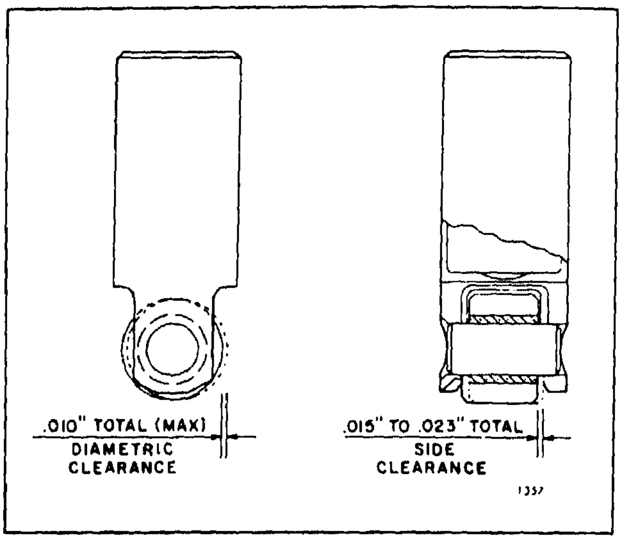


Fig. 5 · Cam Roller Wear and Clearance Diagram

Inspection

Wash the rocker arms, rocker arm shaft and brackets thoroughly in clean fuel oil and dry them with compressed air. Make certain that the oil passages in the rocker arms, rocker arm shaft and bracket bolts are open and clean.

Inspect all of the parts for excessive wear.

The maximum clearance between the rocker arm shaft and the injector rocker arm bushing or an exhaust valve rocker arm (which has no bushing) is .004 " with used parts.

Examine each rocker arm pallet (contact face) for wear or galling. Also check the contact surfaces of the exhaust valve bridge (four valve cylinder heads).

Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)

With the cylinder head removed from the engine, remove the cam followers as follows:

1. Rest the cylinder head on its side and remove the two bolts and lock washers securing the cam follower guide to the bottom of the cylinder head (Fig. 2). Remove the guide.

2. Pull the cam followers from the bottom of the cylinder head.

3. Remove the fuel pipes from the injector and the fuel connectors.

4. Loosen the lock nuts at the upper end of the push rods and unscrew the push rods from the rocker arm clevises.

5. Pull the push rod and spring assemblies from the bottom of the cylinder head.

6. Remove the push rod lock nut, upper spring seat, spring and lower spring seat from each push rod for cleaning and inspection.

The push rod spring seat retainers remain in the cylinder head. If the head is to be changed, these retainers must be removed and installed in the new head.

Remove Cam Follower and Push Rod Assembly (Cylinder Head Not Removed from Engine)

A push rod, push rod spring, spring seats and cam follower may be removed from the top of the cylinder head by using tool J 3092-01 as shown in Fig. 3.

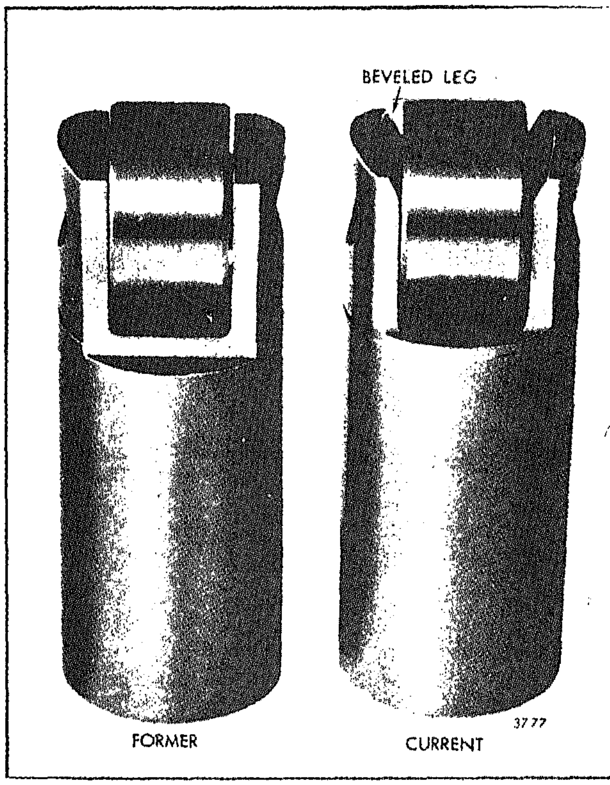


Fig. 6 - Former and Current Cam Followers

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from the injector and the fuel connectors.

3. Remove the rocker arm brackets and rocker arm shaft as outlined in Steps 3 and 4 under *Remove Rocker Arms and Rocker Arm Shaft.*

4. Loosen the lock nut at the upper end of the push rod, next to the clevis, and unscrew the rocker arm from the push rod to be removed. Remove the lock nut from the push rod.

5. Install the remover J 3092-01, a flat washer and nut on the push rod (Fig. 3). Screw the nut down on the end of the push rod to compress the push rod spring.

6. Remove the retainer from the cylinder head with a screw driver or similar tool as shown in Fig. 3.

7. Unscrew the nut at the outer end of the push rod, thus releasing the spring.

8. Pull the push rod, spring, spring seats and cam follower out through the top of the cylinder head.

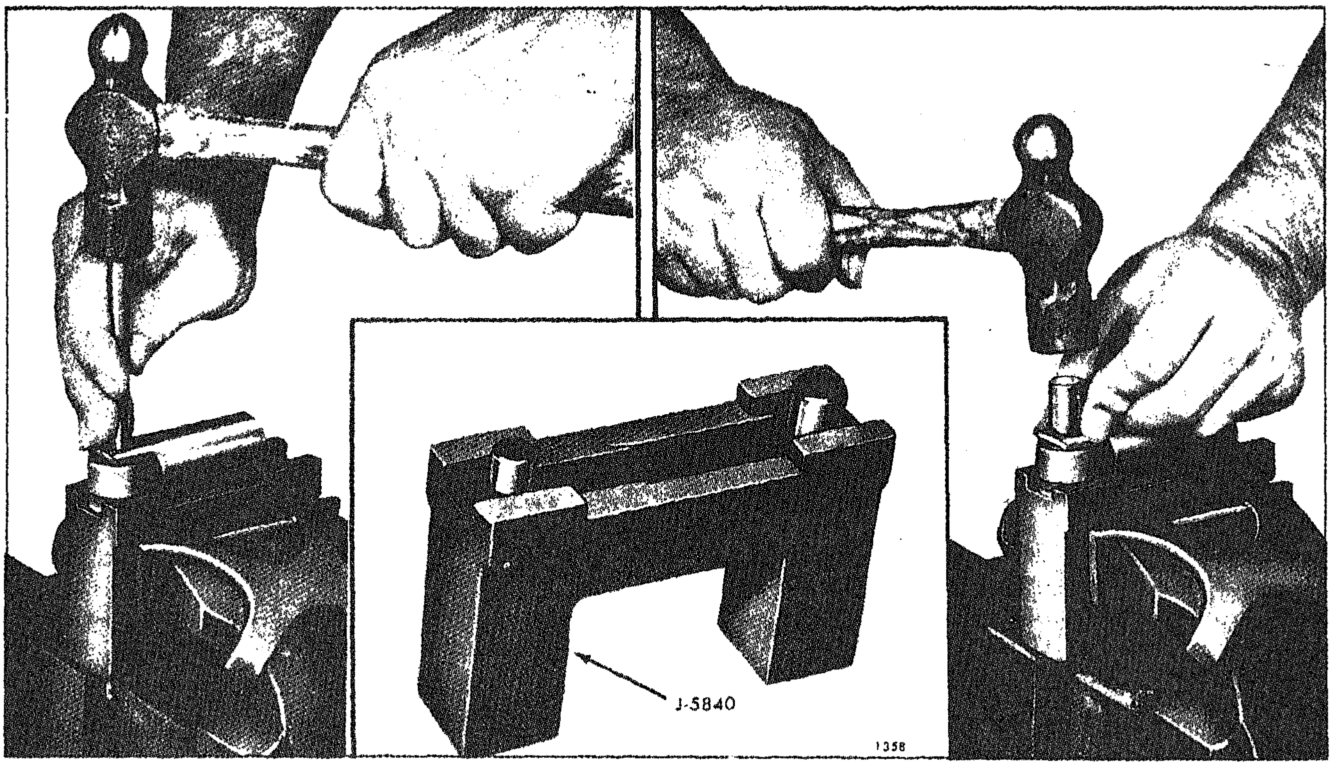


Fig. 7 - Removing or Installing Cam Follower Roller and Pin with Tool J 5840

Inspection

Proper cam follower inspection and service are necessary in obtaining continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, the cam followers, and their related parts, should be removed and inspected for excessive wear. This change in injector timing or exhaust valve clearance during engine operation can usually be detected by excessive noise at idle speed.

After the cam followers are removed, wash them with lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* Fuel oil working its way in between the roller and bushing may cause scoring on the initial engine start-up since fuel oil does not provide adequate lubrication. Wash only the cam follower associated parts with fuel oil and dry them with compressed air.

Inspect the rounded end of the push rods for wear. Replace any push rod which is worn or bent.

The purpose of a push rod spring is to maintain a predetermined load on the cam follower to insure contact of the cam roller on the camshaft lobe at all times. Check the push rod spring load whenever the cam followers and related parts are removed for inspection.

The current push rod spring is made from .192 " diameter wire and was first used only in the injector cam follower position, effective with engine 3D-3792.

Effective with engine 3D-6128 the new spring is also used in the exhaust valve cam follower position. The former push rod spring was made from .177 " diameter wire.

Use spring tester J 9666 and an accurate torque wrench to check the push rod spring load (Fig. 4). Replace the current type spring when a load of less than 250 pounds will compress it to a length of 2-9/64 ". Replace the former type spring when a load of less than 172 pounds will compress it to a length of 2-1/8 ".

It is recommended that if one former type push rod spring requires replacement, all of the former type springs in either the injector or valve cam follower positions be replaced by the current type spring. A new design upper spring seat is required with the use of the current push rod spring.

Examine the cam follower bores in the cylinder head

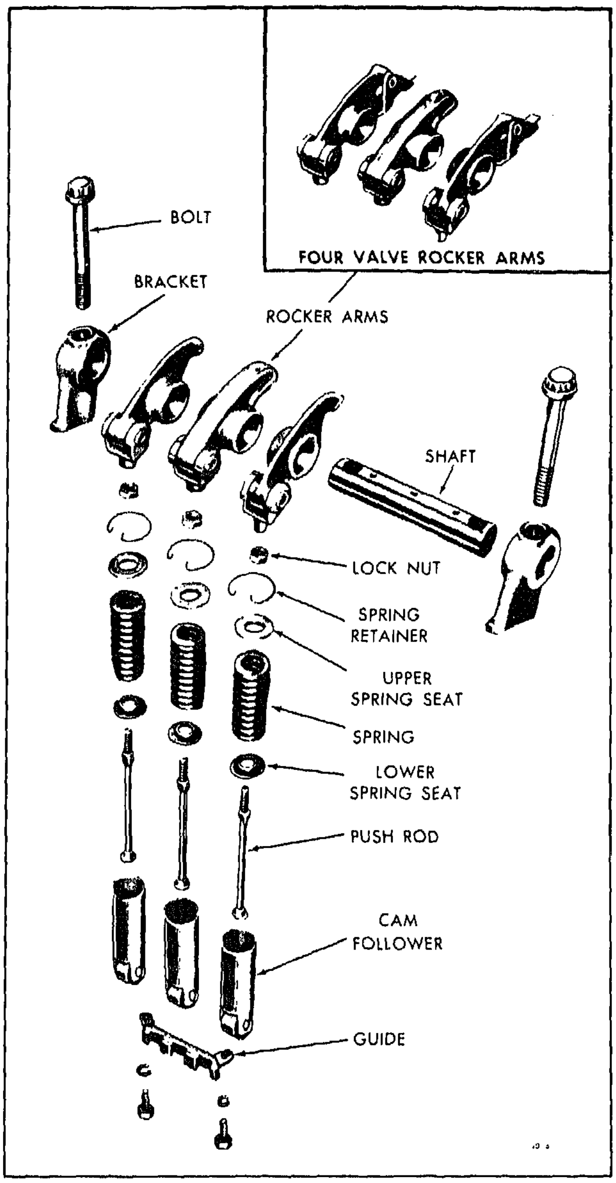


Fig. 8 - Valve and Injector Operating Mechanism Details and Relative Location of Parts

to make sure they are clean, smooth and free of score marks to permit proper functioning of the cam followers. Any existing score marks must be cleaned up.

Check the cam follower-to-cylinder head clearance. The clearance must not exceed .006 " with used parts. If replacement of a cam follower is necessary, use the correct type service cam follower to be assured that the cam roller will receive the proper lubrication.

The cam follower roller must turn smoothly and freely on its pin and the roller must be free from flat spots or scuff marks. If the roller does not turn freely or has been scored or worn flat, then examine the cam on which it operates. If the cam is excessively worn or damaged, replace the camshaft.

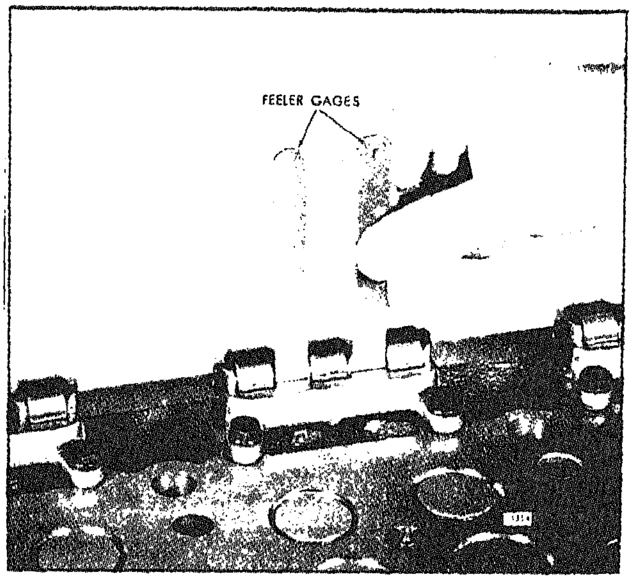


Fig. 9 - Checking the Clearance Between the Cam Follower Guide and Cam Follower Legs

Measure the total clearance between the roller bushing and pin, crosswise of the pin, as shown in Fig. 5 and, if the bushing is worn to the extent that more than

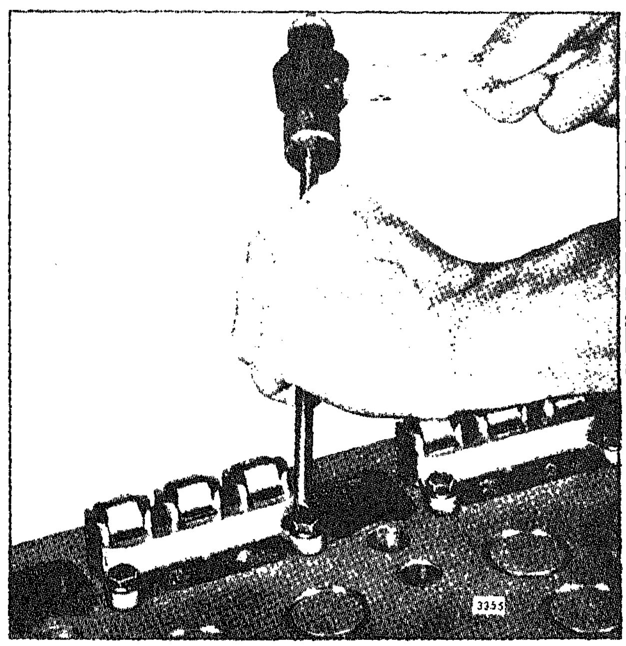


Fig. 10 Adjusting Cam Follower Guide

.010 " diametric clearance exists, replace the cam follower assembly or install a new cam roller and pin, which are serviced as a set. Be sure the follower legs are beveled (Fig. 6) and check the total side clearance between the roller and follower; this clearance must not be less than .015 " nor more than .023 ".

Oversize roller and pin sets are available for service when required. However, DO NOT attempt to bore out the legs of a standard cam follower for an oversize roller and pin set. This cannot be over emphasized because of the extremely close manufacturing tolerances.

NOTE: Cam follower assemblies with the letter "S" stamped on the end of the roller, pin and on one leg of the cam follower body are equipped with oversize roller and pin sets.

Remove and Install Cam Follower Roller and Pin

1. Clamp fixture J 5840 securely in a vise as shown in Fig. 7 and place the cam follower in the groove in the top of the fixture with the follower pin resting on top of the corresponding plunger in the fixture.

2. Drive the pin from the roller with a suitable drift. Exercise caution in removing the cam follower body and roller from the fixture as the follower pin is seated on top of a spring-loaded plunger in the fixture body.

3. Before installing the new roller and pin kit, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705. *Do not use fuel oil.*

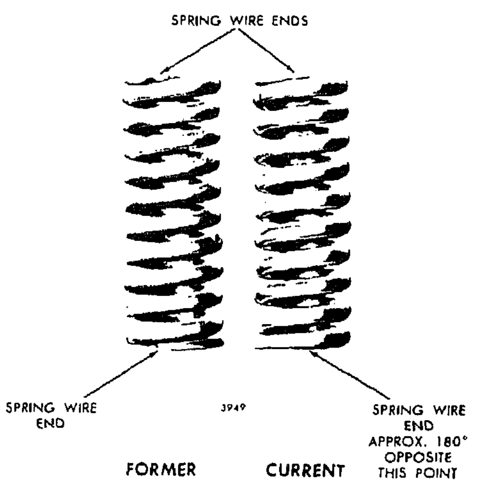


Fig. 11 - Push Rod Spring Identification

4. Prior to installing a new roller and pin, remove any burrs on the surfaces of the cam follower at the pin holes.

5. Position the follower body in the groove of the fixture with the proper size fixture plunger extending through the roller pin hole in one of the legs of the follower body.

6. Position the roller in the cam follower body (Fig. 7). The small plunger in the tool will align the roller with the pin holes in the follower body.

7. Align the pin with the hole in the follower body and carefully drive the pin into the body until the ends of the pin are centered in the legs of the body.

8. Check the side clearance between the roller and the follower body. This clearance must be .015 " to .023 ".

Install Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)

1. Install a serrated lower spring seat on each push rod. If the engine being assembled was equipped with plain lower spring seats, replace them with serrated spring seats (Fig. 8).

2. Place the push rod springs (Fig. 11) on the push rods.

3. Install the proper upper spring seat on each push rod. The cup shaped spring seat used with the current type push rod spring may also be used with the former spring.

4. Install the spring seat retainer in the cylinder head. Then slide the push rod, lower spring seat, spring and upper spring seat as an assembly into the cam follower bore from the bottom of the cylinder head.

5. Screw the push rod lock nut down on the upper end of the push rod as far as possible. Then screw the push rod into the clevis until the end of the rod is flush with or above the inner side of the clevis.

6. Immerse the cam follower assemblies in clean Cindol 1705 (heated to 100 °-125 °F.) for at least one hour before placing them in the cylinder head, to ensure initial lubrication between the cam follower roller pins and the roller bushings. Rotate the cam follower roller during the soaking period to aid in purging any air from the bushing-roller area. The heated Cindol 1705 results in better penetration as it is less viscous than engine oil and flows more easily between the pin and roller bushing surfaces. After the cam follower is removed from the Cindol 1705, the cooling action of any trapped air in the pin and bushing area tends to pull the oil into the cavity.

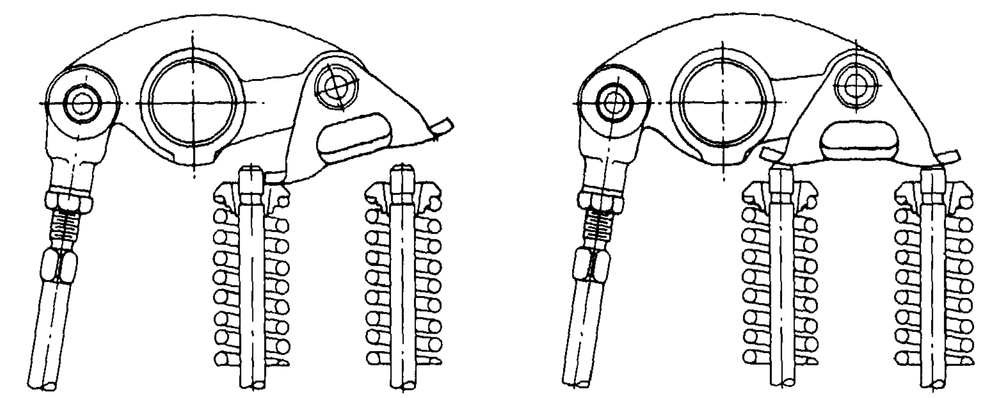


Fig. 12 - Relationship Between Exhaust Valve Bridge and Valve Stems

NOTE: Heat the Cindol 1705 in a small pail, with a screen insert. The screen insert will prevent the follower assemblies from touching the bottom of the pail during soaking, thus avoiding the possibility of contamination.

IMPORTANT: When installing a new cam follower assembly, wash it with clean lubricating oil or Cindol 1705 to remove the preservative.

7. Note the oil hole in the bottom of the cam follower. With this oil hole pointing away from the exhaust valves, slide the cam follower into position from the bottom of the head.

8. Attach the cam follower guide (Fig. 8) to the bottom of the cylinder head to hold the group of cam followers in place. Tighten the cam follower guide bolts to 12-15 lb-ft torque. Check to be sure there is at least .005 " clearance between the cam follower legs and the cam follower guide (Fig. 9). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 10). Then retighten the bolts to 12-15 lb-ft torque and recheck the clearance.

Install Cam Follower and Push Rod Assembly (Cylinder Head Not Removed from Engine)

1. Lubricate the cam follower as stated in Step 6 under *Install Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)*.

2. Note the oil hole in the bottom of the cam follower. With this hole pointing away from the exhaust valves, slide the cam follower into position.

3. Install a serrated lower spring seat on each push rod. If the engine being assembled was equipped with plain lower spring seats, replace them with serrated spring seats.

4. Place the push rod springs (Fig. 11) on the push rods.

5. Install the proper upper spring seat on each push rod. The cup shaped spring seat used with the current type push rod spring may also be used with the former spring.

6. Set the push rod, lower spring seat, spring and upper spring seat down in the cam follower.

7. Install a flat washer and nut on the push rod. Then place tool J 3092-01 on the push rod, between the flat washer and upper spring seat. Screw the nut down on the push rod until the spring is compressed sufficiently to permit the retainer to be installed. Partially collapse the retainer and install it in the cylinder head groove.

8. Remove the nut, flat washer and tool from the push rod.

9. Reinstall the nut on the push rod. Screw the nut down as far as possible on the push rod. Then screw the rocker arm clevis down on the push rod until the end of the push rod is flush with or above the inner side of the clevis.

NOTE: The injector rocker arm (the center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the

shaft on the valve rocker arms is longer on one side of the arm than on the other. The extended boss of the valve rocker arms must face the injector rocker arm.

Install Rocker Arms and Rocker Arm Shaft

1. Install the cylinder head, if removed, as outlined in Section 1.2.

2. Apply clean engine oil to the surface of the rocker arm shaft.

3. Install the rocker arms and rocker arm shaft by reversing the sequence of operations for removal. Tighten the rocker arm shaft bracket bolts to 50-55 lb-ft torque. After tightening the bolts, check for some side clearance to prevent bind between the rocker arms.

CAUTION: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the valve bridges are not resting on the ends of the valves when tightening the rocker arm shaft bracket bolts (Fig. 12). Therefore, note the position of the exhaust valve bridges before, during and after tightening the rocker arm shaft bracket bolts.

4. Align the fuel pipes and connect them to the injectors and the fuel connectors. Tighten the fuel pipe nuts to 12-15 lb-ft torque with socket J 8932-01.

CAUTION: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

5. Fill the cooling system.

6. Adjust the exhaust valve clearance and time the fuel injector as outlined in Section 14.1 and 14.2 before starting the engine.

7. Start the engine and check for leaks in the fuel, cooling and lubrication systems.

8. Tune-up the engine, as outlined in Section 14, after the engine reaches normal operating temperature.

EXHAUST VALVES

Four exhaust valves are provided for each cylinder (Fig. 1). The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the rocker arm or the exhaust valve bridge.

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head. Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head. The exhaust valves and exhaust valve seat inserts are ground to a 30 ° seating angle.

The exhaust valve springs are held in place by the valve spring caps and tapered two-piece valve locks.

Excess oil from the rocker arms lubricates the exhaust valve stems. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leak-proof seating, valve stems must work freely and smoothly within the valve guides and the correct valve clearance (Section 14.1) must be maintained.

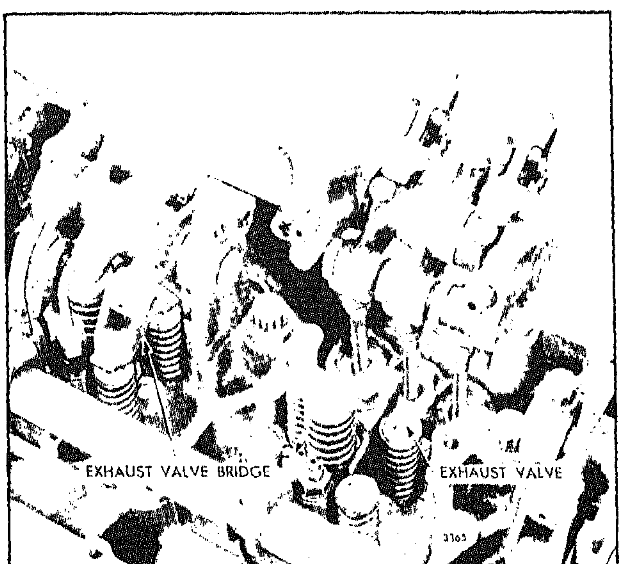


Fig. 1 · Location of Exhaust Valves

Proper maintenance and operation of the engine is important to long valve life. Engine operating temperatures should be maintained between 160 °F. and 185 °F. Low operating temperatures (usually due to extended periods of idling or light engine loads) result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubricating oil to sludge.

Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures.

When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide, sticking valves will result. Thus, the valves cannot seat properly and pitted and burned valves and valve seats and loss of compression will result.

Lubricating oil and oil filters should be changed periodically to avoid accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of antifreeze (glycol) into the lubricating oil which forms a soft sticky carbon and gums the valve stems, and bent or worn valve guides. Sticking valves may eventually result in valves being held in the open position, being struck by the piston and becoming bent or broken.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors will have adverse effects upon combustion. Tightly adjusted valves will cause rapid pitting of the valve seats and a hotter running condition on the valve stems.

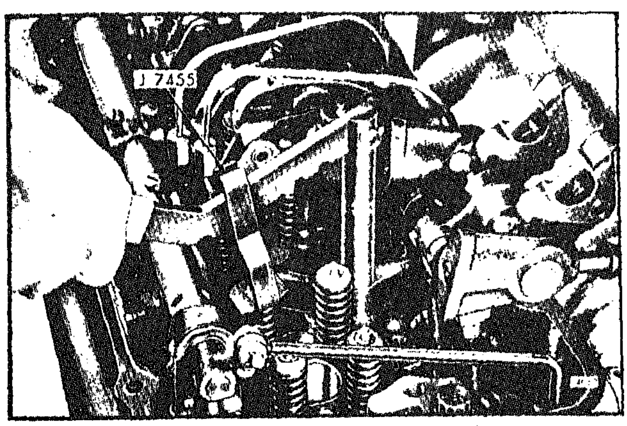


Fig. 2 · Removing Valve Spring

The cylinder head must first be removed before the exhaust valves, valve seat inserts or valve guides can be removed for replacement or reconditioning. However, the valve springs may be replaced without removing the cylinder head.

Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:

1. Clean and remove the valve rocker cover.

2. Crank the engine over to bring the valve and injector rocker arms in line horizontally.

3. Disconnect and remove the fuel pipes from the injector and the fuel connectors.

CAUTION: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

4. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head and remove the brackets and shaft.

5. Remove the cylinder block air box cover so that the piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.

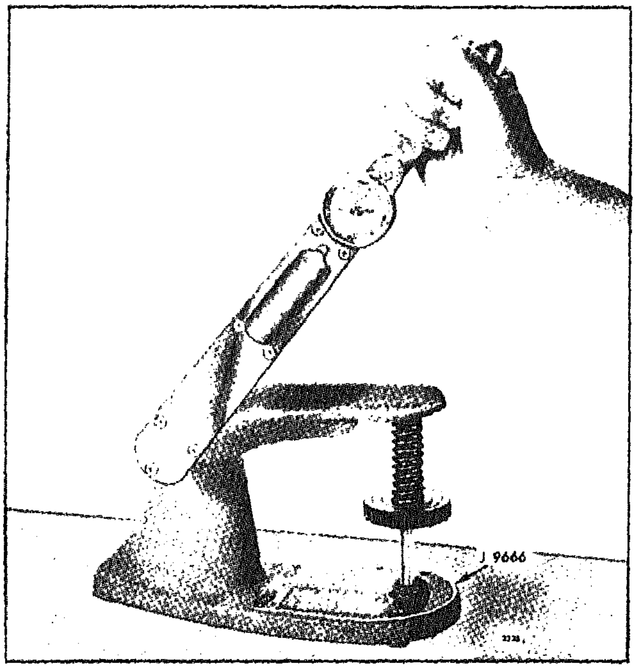


Fig. 3 - Testing Valve Spring

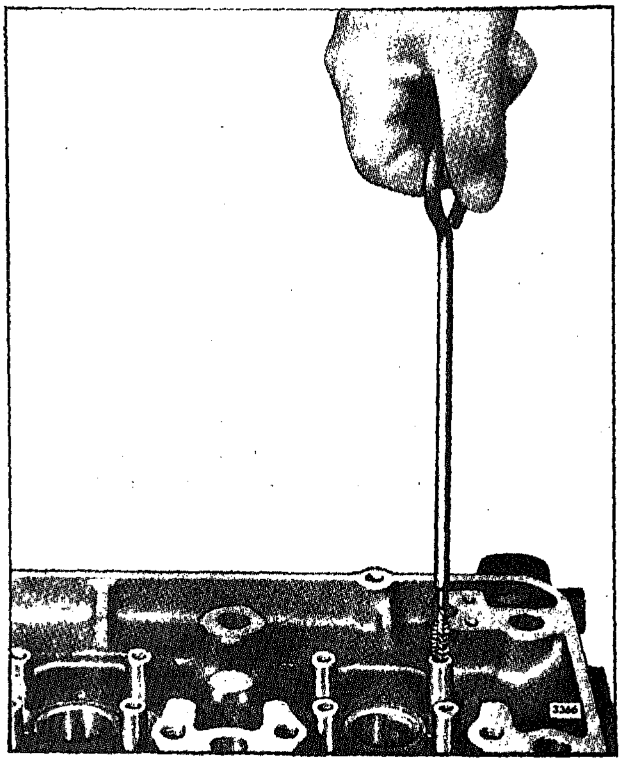


Fig. 4 - Cleaning Valve Guide

6. Thread the spring compressor tool into one of the rocker arm support bolt holes (Fig. 2). Then compress the spring and remove the two-piece valve lock.

7. Release the tool and remove the valve spring cap, valve spring and spring seat.

Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the exhaust valves and springs as follows:

1. Support the cylinder head on 2 " thick wood blocks to keep the cam followers clear of the bench.

2. Disconnect and remove the fuel pipes from the injectors and the fuel connectors.

CAUTION: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

3. Remove the two bolts holding the rocker arm shaft

brackets to the cylinder head and remove the brackets and the shaft.

4. Remove the fuel injector.

5. Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in Steps 6 and 7 above.

6. Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be reused, number each valve to facilitate re-installation in the same position. Then withdraw the valves from the cylinder head.

7. Remove the cam followers and push rod assemblies as outlined in Section 1.2.1 under *Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).*

Inspection

Clean the springs with fuel oil, dry them with compressed air and inspect them. Replace a pitted or fractured spring.

Check the springs with spring tester J 9666 and an accurate torque wrench. Replace a spring if a load of less than 33 pounds will compress a two valve cylinder head spring to 2.31 inches, or a load of less than 25 pounds will compress a four valve cylinder head spring to 1.93 inches. The difference in the load between a pair of four valve cylinder head springs must not exceed 6 pounds or the valve bridge will be unbalanced.

Inspect the valve spring seats and caps for wear. If worn, replace with new parts.

Carbon on the face of a valve indicates blow-by due to a faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too light a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures. High operating temperatures are normally due to overloads, inadequate cooling, or improper timing which results in carbonization of the lubricating oil.

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks or pitting. If necessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

If there is evidence of engine oil running down the exhaust valve stem into the exhaust chamber, creating a high oil consumption condition because of excessive idling and resultant low engine exhaust back pressure, replace the valve guide oil seals or, if not previously used, install valve guide oil seals.

Clean the inside diameter of the valve guides with brush J 7793 (four valve head) as shown in Fig. 4. This brush will remove all gum and carbon deposits from the valve guides.

Inspect the valve guides for fractures, scoring or excessive wear. Check the valve-to-guide clearance, since worn valve guides may eventually result in improper valve seat contact. If the clearance exceeds .005 " (four valve head), replace the valve guides.

The current valve guides, which are not machined for use with oil seals, have a 45 ° chamfer at the upper end. They replace the former 15 ° chamfer valve guides for service.

Remove Exhaust Valve Guide

1. Support the cylinder head, bottom side up, on 3" thick wood blocks.

2. Drive the valve guide out of the cylinder head with valve guide remover J 7775 (four valve head) as shown in Fig. 5.

Install Exhaust Valve Guide

Turn the cylinder head right side up and install the valve guide as follows:

1. Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to the *Valve Guide Installing Tool* chart). Be sure to use the correct tool to avoid damage to the valve guide and to locate the valve guide to the proper dimension.

2. Position the valve guide squarely in the bore in the cylinder head and press the installing tool gently to start the guide in place (Fig. 6). Then press the guide in until the tool contacts the cylinder head (the bottom of the counterbore in the four valve cylinder head).

CAUTION: Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

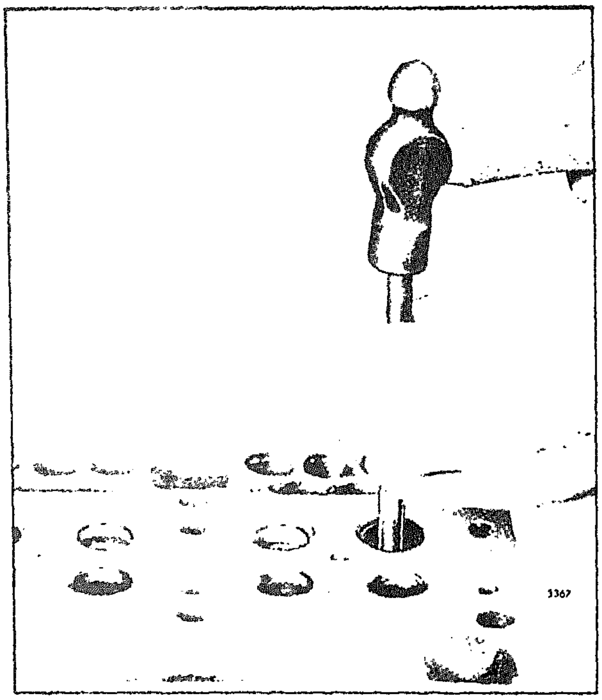


Fig. 5 - Removing Valve Guide

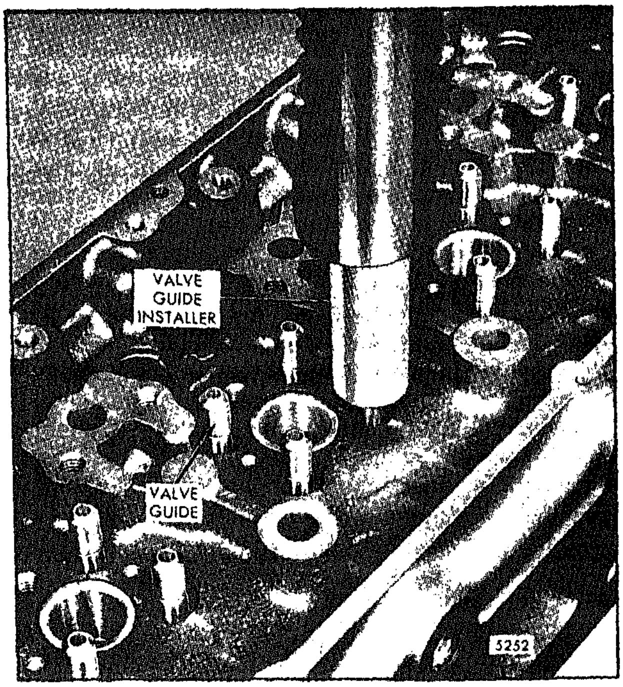


Fig. 6 - Installing Valve Guide

Tool No.	Cyl. Head	Valve Guide	Distance of Guide Below Top of Head
J 7832	4 Valve	15° Chamfer	.010"-.040"
J 9729	4 Valve	45° Chamfer	.010"-.040"
J 9730	4 Valve	*	.190"-.220"

*Machined for use with valve guide oil seal.

Valve Guide Installing Tools

Inspect Exhaust Valve Seat Insert

Inspect the exhaust valve seat inserts for excessive wear, pitting or cracking.

Remove Exhaust Valve Seat Insert

The valve seat inserts are pressed into the cylinder head and must be removed as outlined in the following procedure to avoid damage to the cylinder head:

1. Place the cylinder head on its side on a bench as shown in Fig. 7.

2. Place the collet of tool

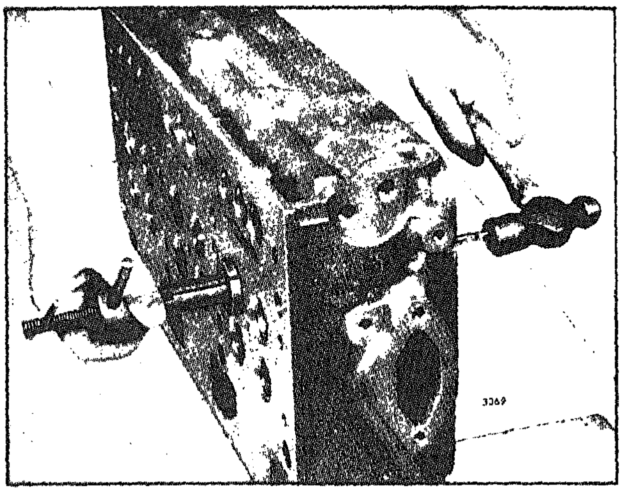


Fig. 7 - Removing Valve Seat Insert

J 7774 (four valve head) inside the valve insert so that the bottom of the collet is flush with the bottom of the insert.

3. Hold the collet handle and turn the T handle to expand the collet cone until the insert is held securely by the tool.

4. Insert the drive bar of the tool through the valve guide.

5. Tap the drive bar once or twice to move the insert about 1/16 " away from its seat in the cylinder head.

6. Turn the T handle to loosen the collet cone and move the tool into the insert slightly so the narrow flange at the bottom of the collet is below the valve seat insert.

7. Tighten the collet cone and continue to drive the insert out of the cylinder head.

Install Exhaust Valve Seat Insert

1. Clean the valve seat insert counterbores in the head with trichloroethylene or other suitable solvent. Also wash the valve seat inserts with the same solvent. Dry the counterbores and the inserts with compressed air.

2. Inspect the counterbores for cleanliness, concentricity, flatness and cracks.

The counterbores in a four valve head have a diameter of 1.159 " to 1.160 " and a depth of .294 " to .306 " on former engines and a depth of .300 " to .312 " on current engines.

NOTE: Valve seat inserts which are .010 " oversize on the outside diameter are available, if required.

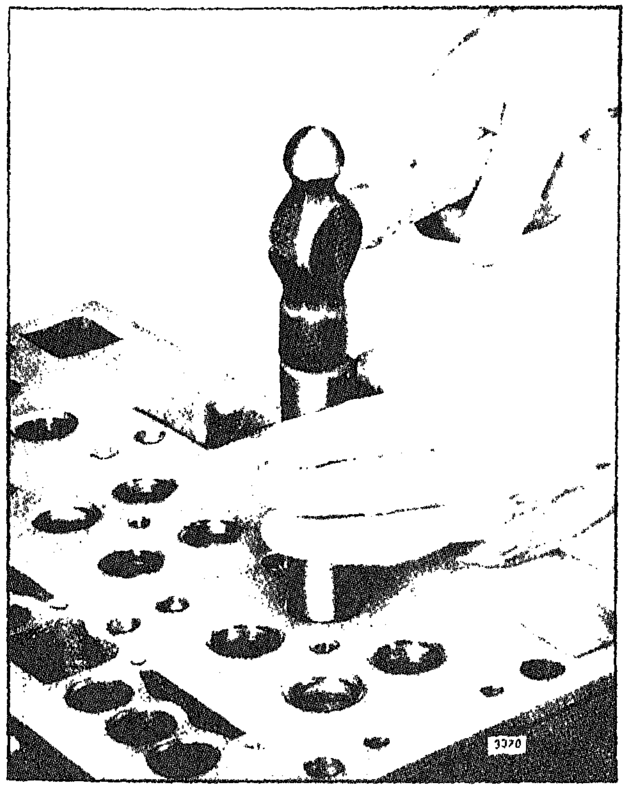


Fig. 8 - Installing Valve Seat Insert

3. Immerse the cylinder head for at least 30 minutes in water heated to 180 °F. to 200 °F.

4. Rest the cylinder head, bottom side up, on a bench and place an insert in the counterbore--valve seat side up. This must be done quickly while the cylinder head is still hot and the insert is cold (room temperature). If the temperature of the two parts is allowed to become nearly the same, installation may become difficult and damage to the parts may result.

5. Drive the insert in place with installer J 7790 (four valve head) as shown in Fig. 8 until it seats solidly in the cylinder head.

6. Grind the valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

Recondition Exhaust Valve and Valve Seat Insert

An exhaust valve which is to be reused may be refaced, if necessary (Fig. 9). To provide sufficient valve strength and spring tension, the edge of the

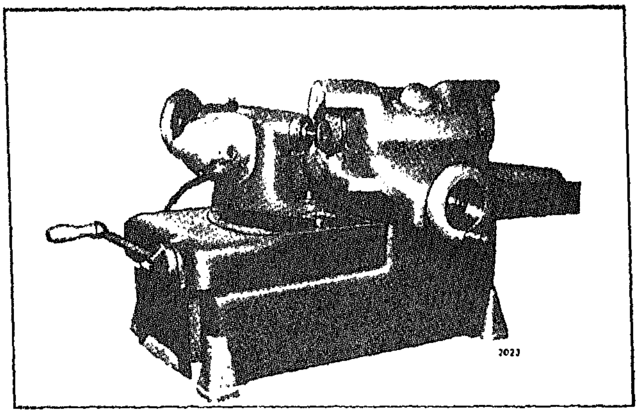


Fig. 9 · Refacing Exhaust Valve

valve at the valve head must not be less than 1/32 " in thickness and must still be within the specifications shown in Figs. 11 and 12 after refacing.

Before either a new or used valve is installed, examine the valve seat in the cylinder head for proper valve seating. The angle of the valve seat insert must be exactly the same as the angle of the valve face to provide proper seating of the valve. The proper angle for the seating face of both the valve and valve seat insert is 30 °.

When a new valve seat insert is installed or an old insert refaced, the work must be done with a grinding wheel (Fig. 10).

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method

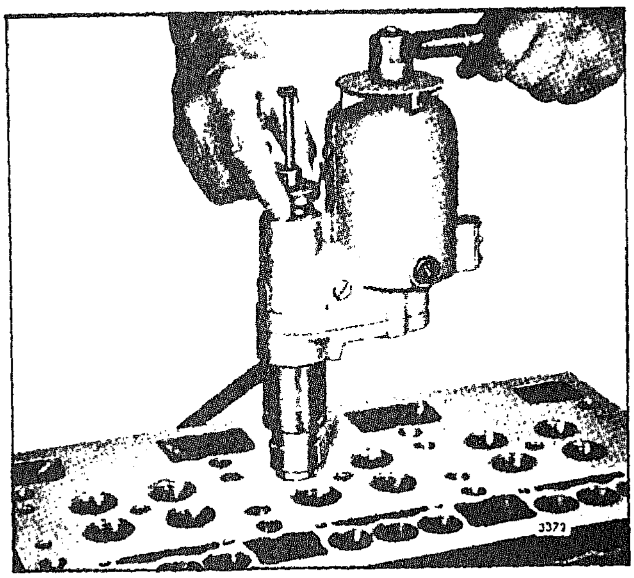


Fig. 10 · Grinding Valve Seat Insert

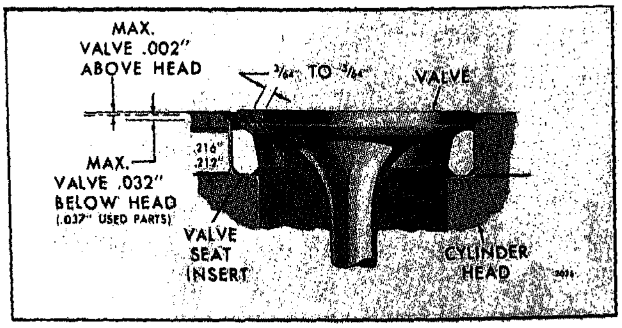


Fig. 11 · Relationship Between Exhaust Valve, Insert and Cylinder Head (Two Valve Head)

produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits feeding the grinding wheel into the work .001 " at a time.

To grind the valve seat inserts for a four valve cylinder head, use the following tools:

1. Grinder J 8165-1
2. Dial Gage J 8165-2
3. Pilot J 7792-1
4. Grinding Wheel (15 °) J 7792-2
5. Grinding Wheel (30 °) J 7792-3
6. Grinding Wheel (60 °) J 7792-4

Grind the valve seat inserts as follows:

1. First apply the 30 ° grinding wheel on the valve seat insert.

2. Use the 60 ° grinding wheel to open the throat of the insert.

3. Then grind the top surface with a 15 ° wheel to narrow the width of the seat from 3/64 " to 5/64 "

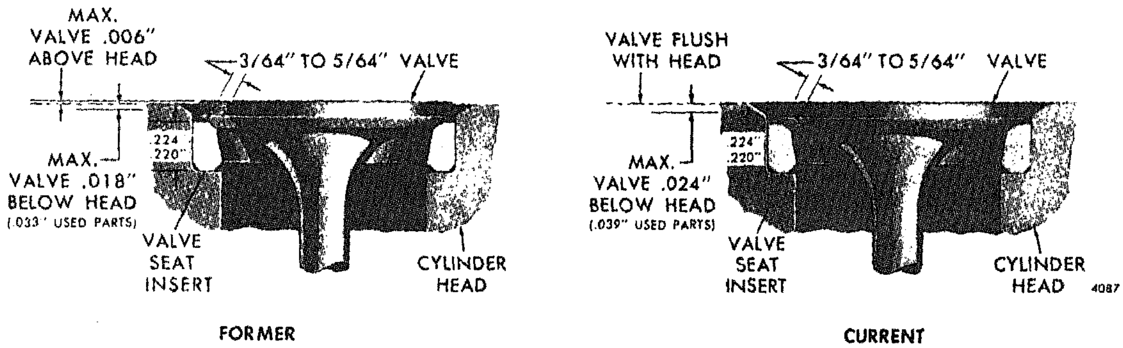


Fig. 12 - Relationship Between Exhaust Valve, Insert and Cylinder Head (Four Valve Head)

(Figs. 11 and 12). The 30 ° face of the insert may be adjusted relative to the center of the valve face with the 15 ° and 60 ° grinding wheels.

CAUTION: Do not permit the grinding wheel to contact the cylinder head when grinding the insert. If necessary, replace the insert.

The maximum amount that the exhaust valve should protrude beyond the cylinder head (when the valve is in the closed position), and still maintain the proper piston-to-valve clearance, is shown in Figs. 11 and 12. Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. If, after several grinding operations, the valve recedes beyond the specified limits, replace the valve seat insert.

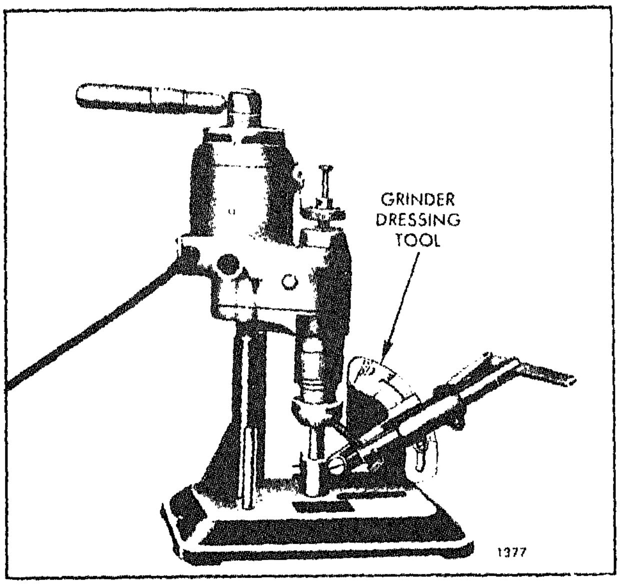


Fig. 13 - Grinding Wheel Dressing Tool of Set J 8165

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Fig. 13).

After grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165-2 in position as shown in Fig. 14 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. If the runout exceeds .002 ", check for a bent valve guide before regrinding the insert.

4. After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:

a. Apply a light coat of Prussian Blue or similar paste to the valve seat insert.

b. Lower the stem of the valve in the valve guide and "bounce" the valve on the seat. *Do not rotate the valve.* This procedure will show the area of contact (on the valve face). The most desirable area of contact is at the center of the valve face.

After the valve seat inserts have been ground and checked, thoroughly clean the cylinder head before installing the valves.

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications shown in Figs. 11 and 12. Also, do not use "N" pistons with former four valve cylinder head assemblies unless the valves are flush with the cylinder head. If the valves are not flush, it may be necessary to regrind the valve seats so that

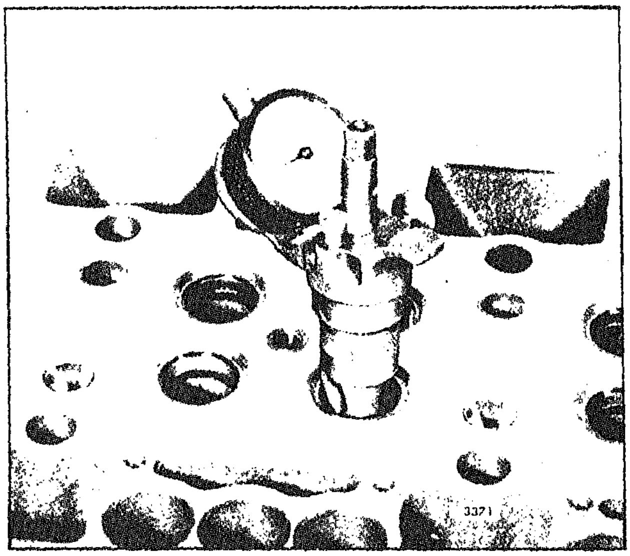


Fig. 14 - Checking Relative Concentricity of Valve Seat Insert with Relation to Valve Guide

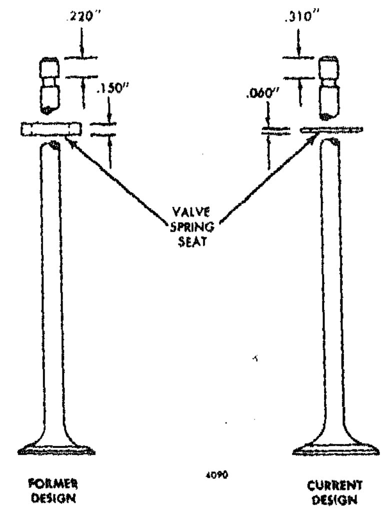


Fig. 15 - Former and Current Design Exhaust Valves (Four Valve Head)

the valves will be flush with the bottom surface of the cylinder head.

NOTE: The distance from the top of the four valve cylinder head to the bottom of the valve spring seat counterbore is 1-11/64 " in current design cylinder heads or 1-5/64 " in former design heads.

Be sure and install the correct parts in the four valve cylinder head. Current design cylinder heads are equipped with the thin valve spring seats (.060 ") and current design exhaust valves (Fig. 15). To facilitate replacement of a four valve head on an engine using the former exhaust valves, the proper quantity of the thick spring seats (.150 ") must be used.

Service cylinder heads are of the current design. The current thin valve spring seats (.060 ") are included with each cylinder head as a shipped loose item.

1. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides.

IMPORTANT: If reconditioned valves are used, install them in the same relative location from which they were removed.

2. Hold the valves in place temporarily with a strip of masking tape. Then, turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.

3. Install the valve spring seats.

4. Install the valve guide oil seals, if used, on the valve guides as follows:

a. Place the plastic seal installation cap on the end of the valve stem. If the cap extends more than 1/16 " below the groove on the valve stem, remove the cap and cut off the excess length.

b. Lubricate the installation cap and start the seal carefully over the valve stem. Push the seal down slowly until it rests on top of the valve guide.

c. Remove the installation cap.

5. Install the valve springs and valve spring caps.

6. Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 2).

7. Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring. Tap the end of the valve stem lightly with a plastic hammer to seat the valve locks.

NOTE: If valve guide oil seals are used, compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

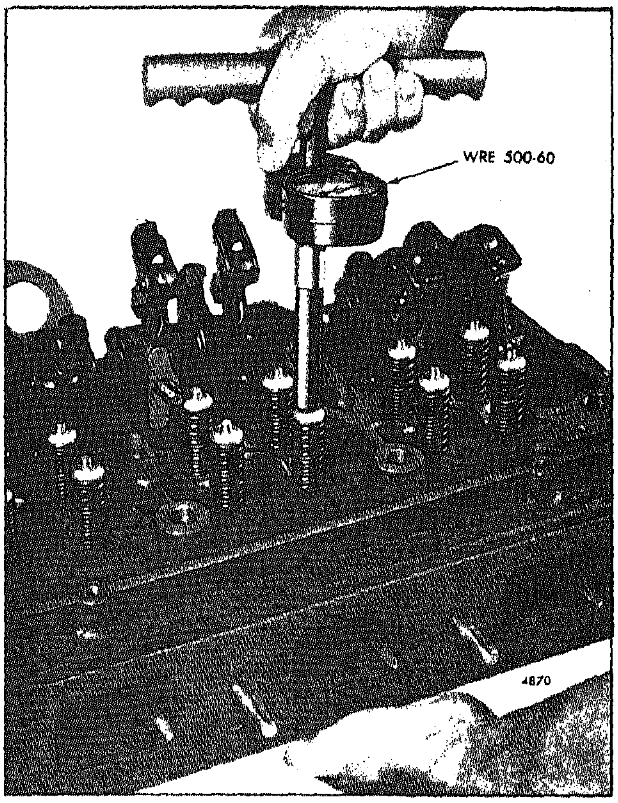


Fig. 16 · Checking Valve Opening Pressure with Gage WRE-500-60

8. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

9. Check the position of the exhaust valve (Fig. 11).

10. With the exhaust valves installed in the cylinder head, use spring checking gage WRE -500-60 and note the gage reading the moment the exhaust valve starts to open (Fig. 16). The minimum pressure required to start to open the exhaust valve must not be less than 25 pounds for a four valve cylinder head.

11. Install the injectors, rocker arms, shafts, brackets and any other parts that were previously removed from the cylinder head.

12. Install the cylinder head. Refer to *Pre-Installation Inspection* and *Install Cylinder Head* in Section 1.2.

13. Perform a complete engine tune-up.

VALVE ROCKER COVER

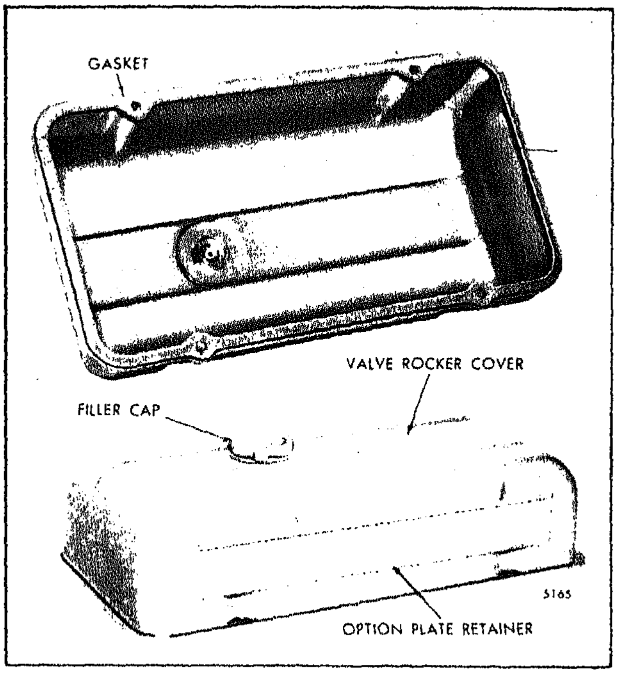


Fig. 1 - Typical Valve Rocker Cover Assembly

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head. The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover.

An option plate is inserted in a retainer (Fig. 1) attached to the cover on each In-Line engine.

The valve rocker cover assembly on certain engines may include a breather assembly or an oil filler, depending upon the engine application.

Remove and Install Valve Rocker Cover

Clean the valve rocker cover before removing it from the engine to avoid dust or dirt from entering the valve mechanism. Then remove the valve cover screws and lift the cover straight up from the cylinder head. Use a new gasket when re-installing the cover.

CRANKSHAFT

The crankshaft (Fig . 1) is a one-piece steel forging, heat-treated to ensure strength and durability. All main and connecting rod bearing journal and oil seal surfaces are induction hardened.

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end play is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

On In-Line engines, six tapped holes are provided in the rear end of the crankshaft for attaching the flywheel.

In-line engine main bearing journals are 3″ in diameter and the connecting rod journals are 2-1/2″ in diameter.

Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Clean the exterior of the engine.

2. Drain the cooling system.

3. Drain the engine crankcase.

4. Remove all engine to base attaching bolts. Then, with a chain hoist and sling attached to the lifter brackets at each end of the engine, remove the engine from its base.

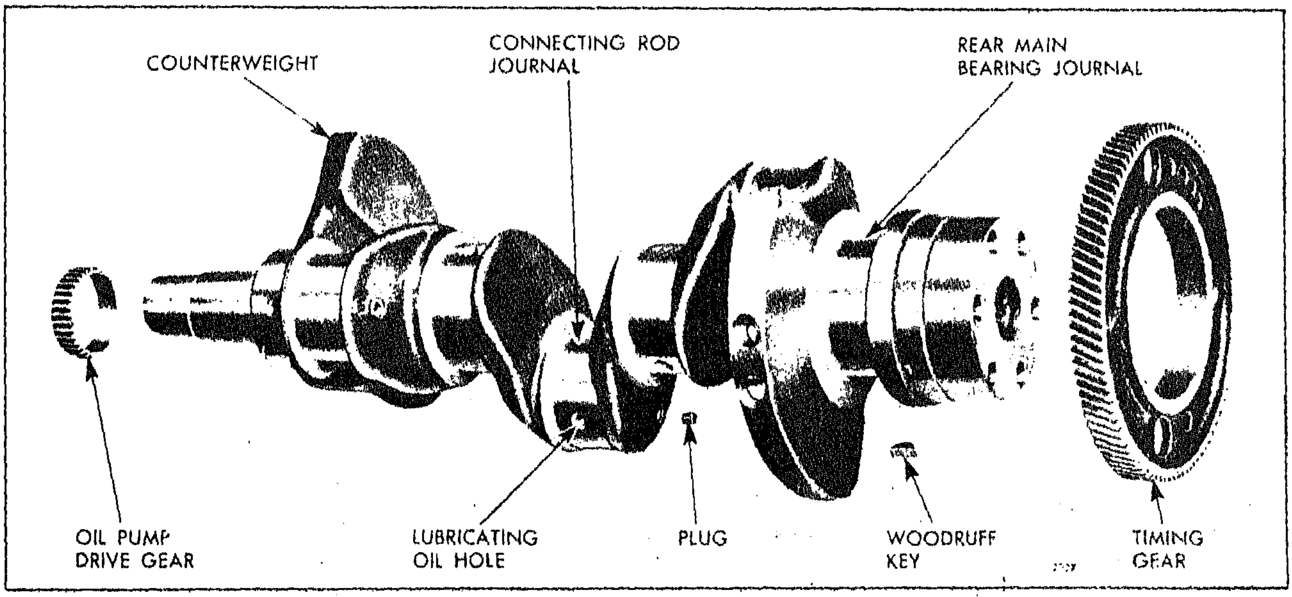


Fig. 1 - Crankshaft Details and Relative Location of Parts (Three Cylinder In-Line Engine Crankshaft Shown)

5. Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.

6. Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

> **CAUTION:** Be absolutely sure the engine is securely attached to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

7. Remove the oil pan.

8. Remove the oil pump inlet pipe and screen.

9. Remove the flywheel and flywheel housing.

10. Remove the crankshaft pulley.

11. Remove the front engine support.

12. Remove the engine lower front cover and oil pump assembly.

13. Remove the cylinder head(s).

15. Remove the connecting rod bearing caps.

16. Remove the main bearing caps.

17. Remove the thrust washers from each side of the rear main bearing.

18. Remove the pistons, connecting rods and liners.

19. Remove the crankshaft, including the timing gear (Fig. 3).

20. Refer to Section 1.7.5 for removal of the crankshaft timing gear and Section 4.1 for the procedure covering removal of the oil pump drive gear.

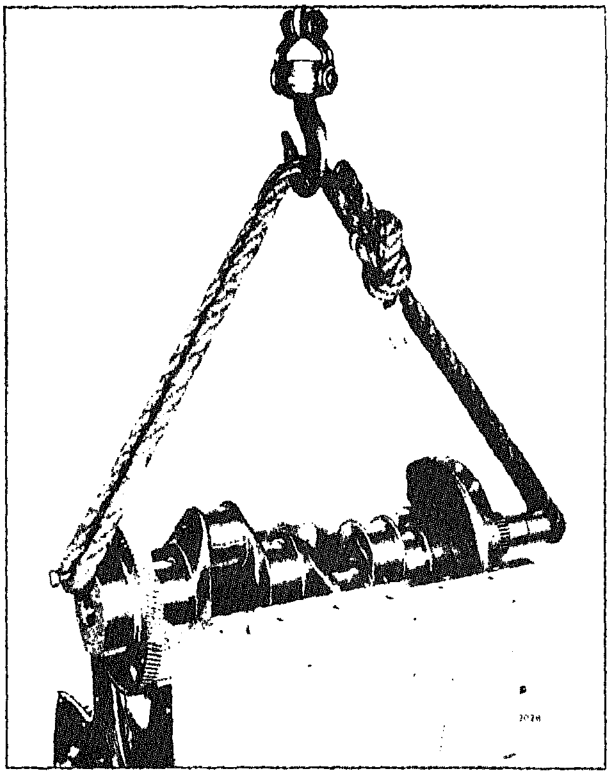


Fig. 3 - Removing or Installing Crankshaft

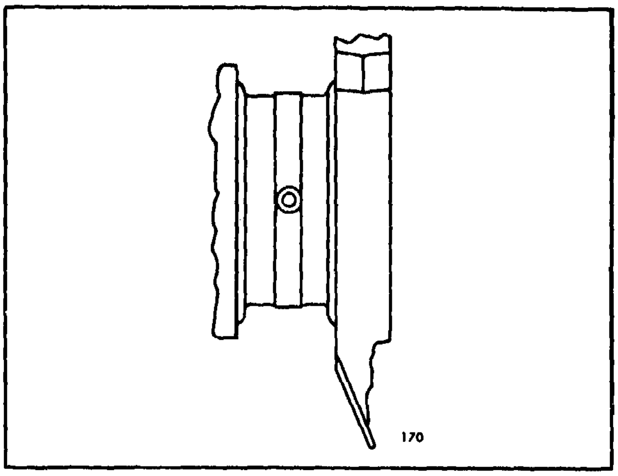


Fig. 4 · Typical Ridging of Crankshaft

Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then reinstall the plugs.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 4). Ridges exceeding .0002″ must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005″, first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .001″, the crankshaft may have to be reground.

Carefully inspect the front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

Slight ridges on the crankshaft oil seal contact surfaces may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily, the oil seals may be repositioned in the flywheel housing and front cover as outlined in Section 1.3.2.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise it will be necessary to regrind the thrust surfaces.

Check the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

Inspect the crankshaft for cracks as outlined under *Inspection for Cracks.*

Crankshaft Measurements

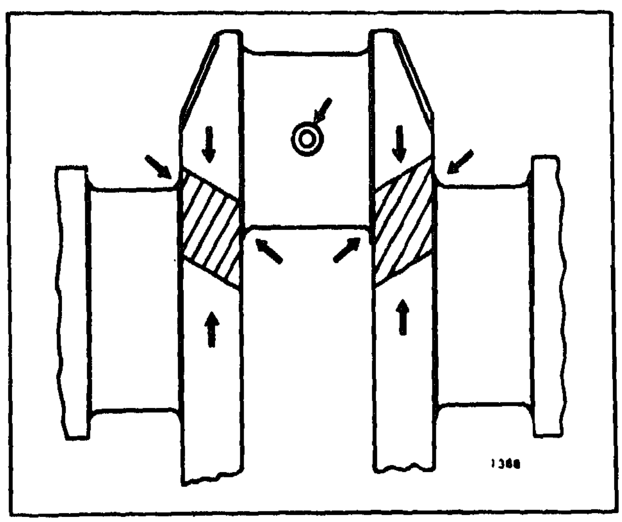


Fig. 5 · Critical Crankshaft Loading Zones

On 3 cylinder in-line crankshafts, the maximum runout on the intermediate journals must not exceed .002" total indicator reading.

Measure all of the main and connecting rod bearing journals (Fig. 7). Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod journal-to-bearing shell clearance (with new shells) exceeds .0045" (In-line engine) or the main bearing journal-to-bearing shell clearance (with new shells) exceeds .0040" (In-line type engines), the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the journal taper or out-of-round is greater than .003", the crankshaft must be reground.

Also measure the crankshaft thrust surfaces (Fig. 10).

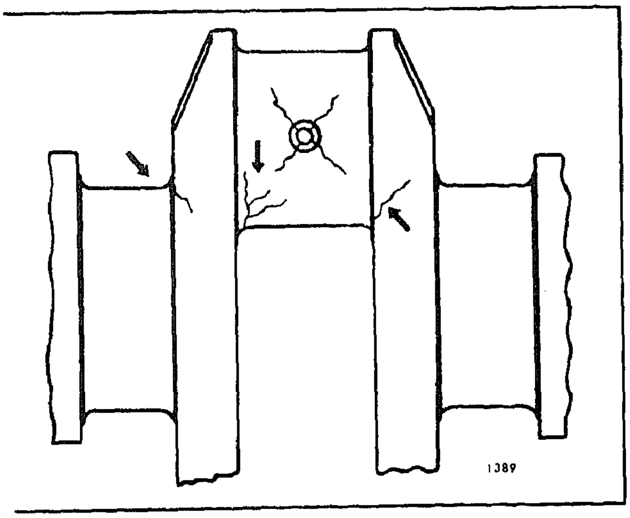


Fig. 6 - Crankshaft Fatigue Cracks

Inspection for Cracks

Carefully check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

Magnetic Particle Method: The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be de-magnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "black light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "black light".

Fluorescent Penetrant Method: This is a method which may be used on *non-magnetic* materials such as stainless steel, aluminum and plastics. A highly fluorescent liquid penetrant is applied to the part. Then the excess penetrant is wiped off and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "black light".

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure. **Interpretation** of the indications is the most important step.

All Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service -- a *bending* force and a *twisting* force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain

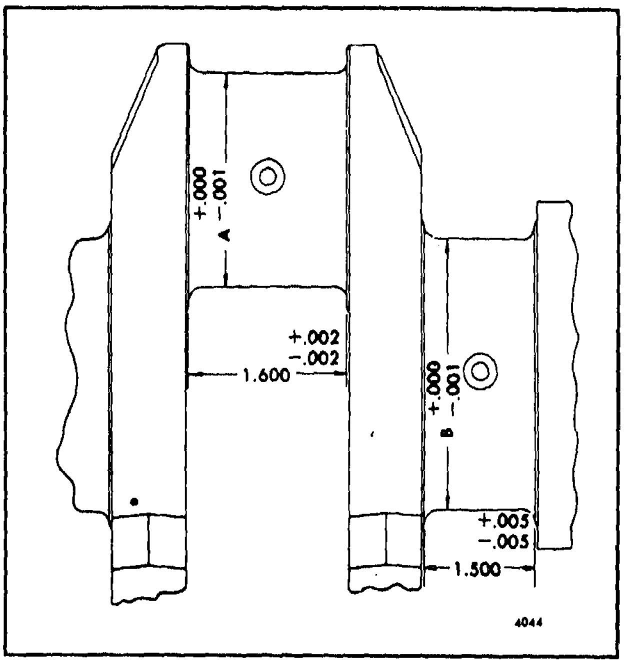


Fig. 7 - Dimensions of Crankshaft Journals - In-Line Engine

small areas, designated as critical areas, sustain most of the load (Fig. 5).

Bending fatigue failures result from bending of the crankshaft which takes place once per revolution.

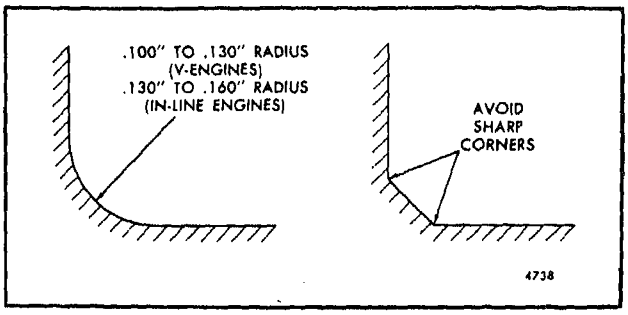


Fig. 9 - Crankshaft Journal Fillets

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional fatigue failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 5.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are usual causes of this type of failure. Also, overspeeding of the engine or resetting the governor at a different speed than intended for the engine application may be contributory factors.

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45°

cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes as shown in Fig. 6. Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002", .010", .020" and .030" undersize bearings are available.

> **NOTE:** The .002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

If the crankshaft is to be reground, proceed as follows:

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 1 and Fig . 7 and determine the size to which the journals are to be reground.

2. If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.

3. All journal fillets on the In-line crankshafts must have a .130" to .160" radius

The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.

4. Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

5. Polish the ground surfaces to an 8-12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

6. If the thrust surfaces of the crankshaft (Fig. 10) are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .130" to .160" radius on the In-line crankshaft between each thrust surface and the bearing journal.

7. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32".

8. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

9. De-magnetize the crankshaft.

10. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

Bearing Size	Conn. Rod Journal Dia.	Main Bearing Journal Dia.
	In-Line Engines	
Standard	2.499"/2.500"	2.999"/3.000"
.002" Undersize	2.497"/2.498"	2.997"/2.998"
.010" Undersize	*2.489"/2.490"	*2.989"/2.990"
.020" Undersize	*2.479"/2.480"	*2.979"/2.980"
.030" Undersize	*2.469"/2.470"	*2.969"/2.970"

*Dimension of reground crankshaft

TABLE 1

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then install the crankshaft as follows:

1. Assemble the crankshaft timing gear (Section 1.7.5) and the oil pump drive gear (Section 4.1) on the crankshaft.

2. Refer to Section 1.3.4 for main bearing details and install the upper *grooved* bearing shells in the block. If the old bearing shells are to be used again, install

Nominal Size	Thrust Washer Thickness Min.	Thrust Washer Thickness Max.
Standard	.1190"	.1220"
.005" Oversize	.1255"	.1270"
.010" Oversize	.1300"	.1320"

TABLE 2

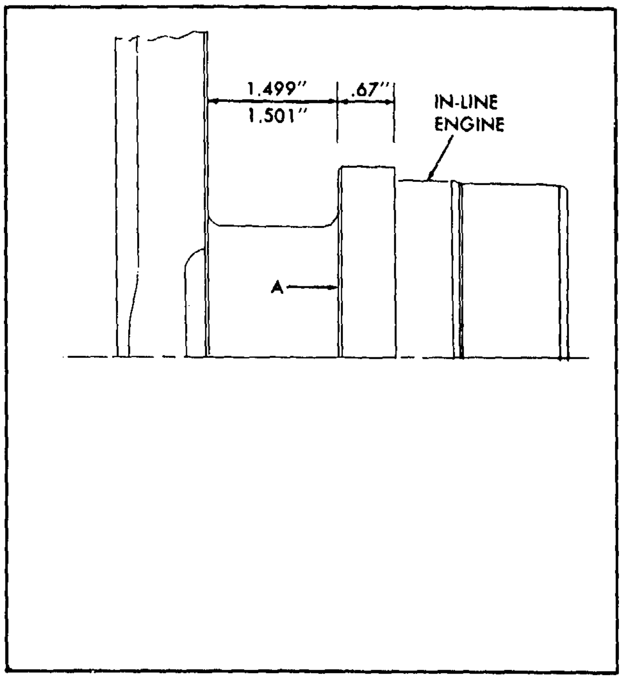


Fig. 10 · Standard Dimensions at Crankshaft Thrust Surfaces--In-Line Engines

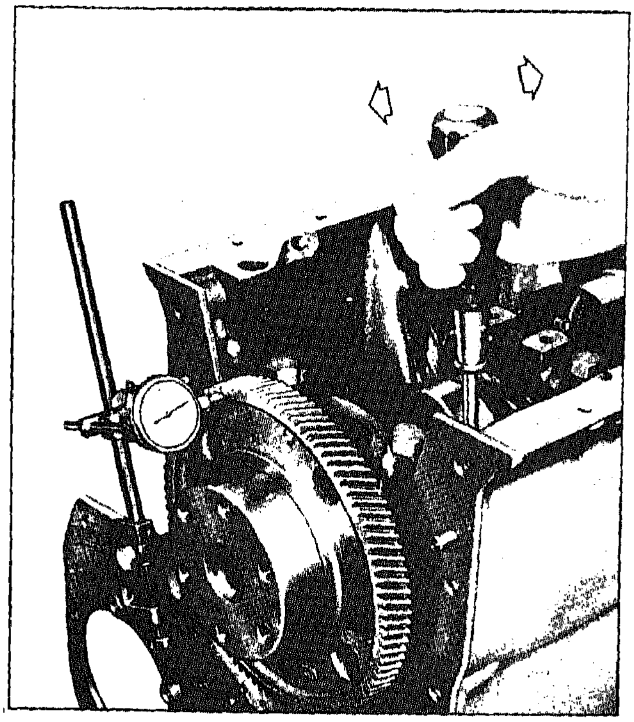


Fig. 11 · Checking Crankshaft End Play

them in the same locations from which they were removed.

NOTE: When a new or reground crankshaft is installed, *ALL* new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

3. Apply clean engine oil to all crankshaft journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to Section 1.7.1 for the correct method of timing the gear train.

4. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. *The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.*

NOTE: If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 10 and Table 2.

5. Install the lower bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

6. Install the main bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells* in Section 1.3.4.

NOTE: If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

7. Check the crankshaft end play by moving the crankshaft toward the gage (Fig. 11) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004" to .011" with new parts or a maximum of .018" with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

8. Install the cylinder liner, piston and connecting rod assemblies (Section 1.6.3).

9. Install the cylinder head(s) (refer to Section 1.2).

10. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4).

11. Install the crankshaft lower engine front cover and the lubricating oil pump assembly on In-line

engine.

12. Install the engine front support, if used.

13. Install the crankshaft pulley (Section 1.3.7).

14. Install the oil pump inlet pipe and screen on In-line engine

(Section 4.1).

15. Affix a new gasket to the oil pan flange and install the oil pan.

16. Use a chain hoist and sling attached to the lifting bracket at each end of the engine and remove the engine from the overhaul stand.

17. Install all of the accessories that were removed.

18. After the engine has been completely reassembled, refer to the *Lubricating Oil Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

19. Close all of the drains and fill the cooling system.

20. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the run-in schedule (Section 13.2.1).

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

The front oil seal is pressed into the lower front cover on In-line engine (Fig. 1).

A single-lip oil seal is used at the rear end of the crankshaft of most industrial engines. A double-lip oil seal is used in engines where there is oil on both sides of the oil seal; the lips of the seal face in opposite directions. The rear oil seal is pressed into the flywheel housing (Fig. 2).

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout or grooved sealing surfaces on the crankshaft. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Remove Crankshaft Oil Seals

Remove the engine front cover (Section 1.3.5), outboard bearing support or the flywheel housing (Section 1.5) and remove the oil seals as follows:

1. Support the forward face of the front cover, or the outboard bearing support, on two wood blocks next to the oil seal bore. Then press or drive the oil seal out of the front cover or the outboard bearing support. Discard the oil seal.

2. Support the forward face of the flywheel housing on In-line engines on two wood blocks next to the oil seal bore. Then press or drive the oil seal out of the housing. Discard the oil seal.

3. Clean the oil seal bore in the front cover, outboard bearing support or flywheel housing thoroughly before installing a new oil seal.

When necessary, an oil seal may be removed without removing the front cover, outboard bearing support or flywheel housing. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars.

Inspection

Inspect the front and rear end of the crankshaft

for wear due to the rubbing action of the oil seal, dirt build-up or fretting caused by action of the flywheel.

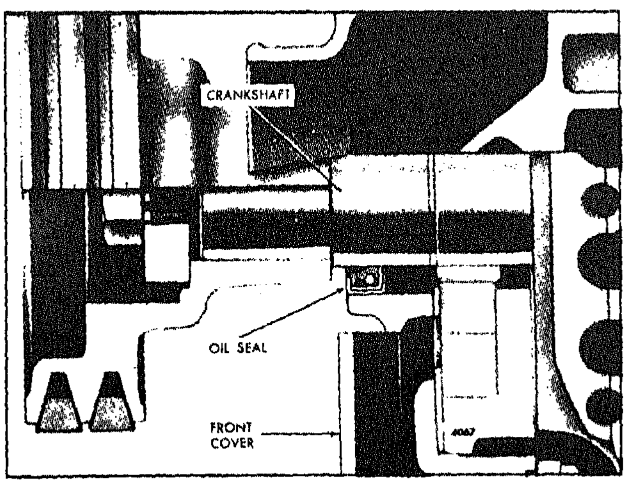


Fig. 1 · Crankshaft Front Oil Seal

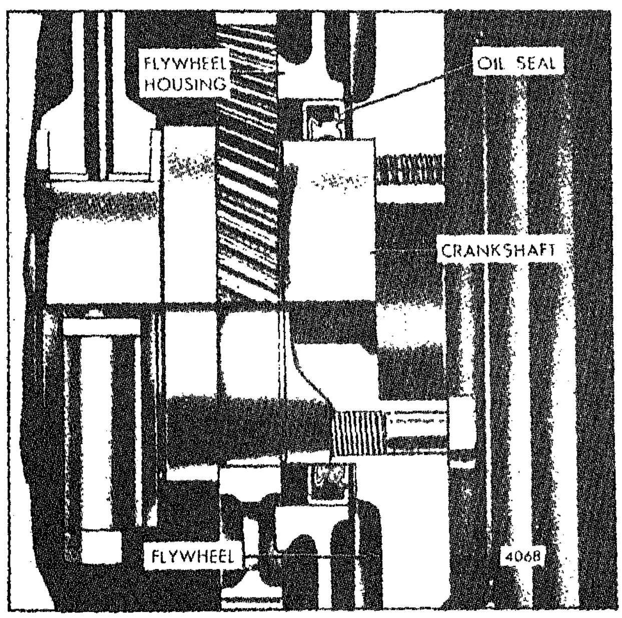


Fig. 2 · Crankshaft Rear Oil Seal (In-Line Engines)

The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under *Inspection* in Section 1.3.

On In-line engines, if the crankshaft cannot be cleaned up satisfactorily, the oil seal may be pressed into the flywheel housing or the front cover 1/8" from its original position.

If excessive wear or grooving is present, install an oil seal sleeve (Figs. 3, and 5) which provides a replaceable wear surface for the lip-type oil seal. The oil seal sleeve may be used with either the single-lip or double-lip type oil seal, and can also be used in conjunction with the seal spacer. However, an oversize oil seal must be used with the sleeve.

Install the rear oil seal sleeve (Fig. 3) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.

2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.

3. Drive the sleeve squarely on the shaft with crankshaft rear oil seal sleeve installer J 21277 (in-line engines).

4. Wipe off any excess sealant.

5. Coat the outside diameter of the sleeve with engine oil.

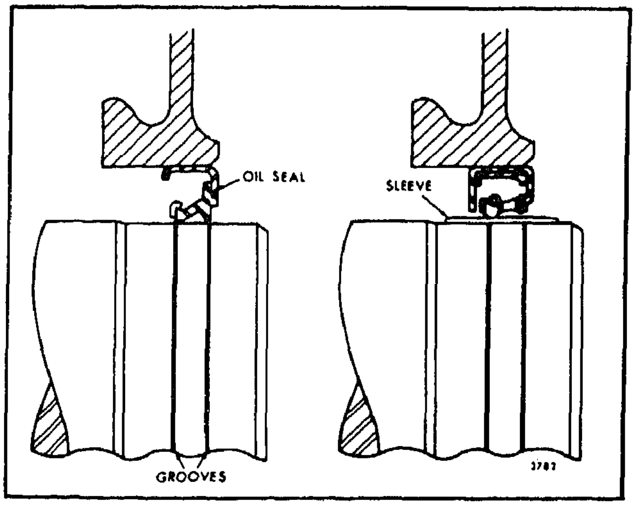


Fig. 3 - Use of Rear Oil Seal Sleeve on Grooved Crankshaft (In-line Engines)

Install the front oil seal sleeve (Fig. 5) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.

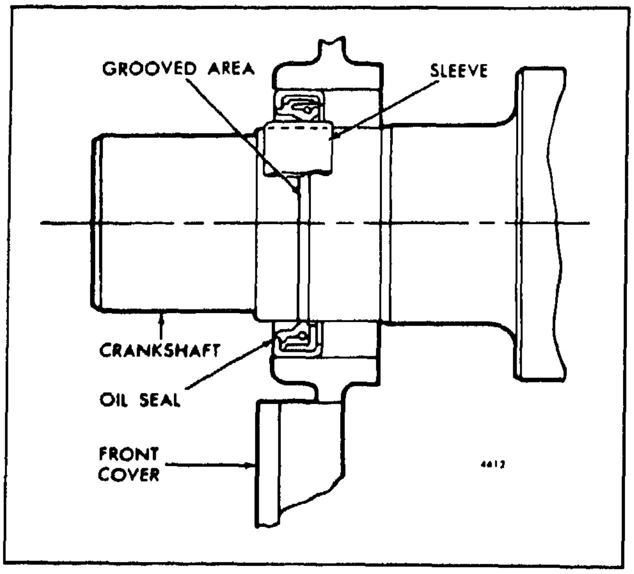


Fig. 5 - Use of Front Oil Seal Sleeve on Grooved Crankshaft (In-line Engines)

2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.

3. Position the sleeve on the crankshaft with the radius on the sleeve facing away from the engine.

4. Drive the sleeve squarely on the shaft with front oil seal sleeve installer J 22524 and the crankshaft pulley retaining bolt.

5. Wipe off any excess sealant.

6. Coat the outside diameter of the sleeve with engine oil.

To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the end of the crankshaft.

Oil Seals

Current oil seals are made of an oil resistant synthetic rubber which is pre-lubricated with a special lubricant. *Do not remove this lubricant.* Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the casing. Do not remove this coating.

Install Crankshaft Front Oil Seal

1. If the oil seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing.

2. Coat the lip of the new oil seal lightly with grease or vegetable shortening. Then position the seal in the cover or outboard bearing support with the lip of the seal pointed toward the inner face of the cover or bearing support.

3. Place the cover or outboard bearing support in an arbor press (inner face down).

4. On In-line engines, use installer J 9783 to press the oil seal into the cover until the seal is flush with the outside face of the cover.

5. Remove any excess sealant.

6. Install the engine front cover (Section 1.3.5) or the outboard bearing support.

Install Crankshaft Rear Oil Seal

1. Support the inner face of the flywheel housing in an arbor press or on a flat surface.

2. If the new seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing. Then position the seal with the lip pointed toward the inner face of the housing.

3. Coat the lip of the oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

4. On In-Line engines, use installer J 9479 to press the oil seal into the flywheel housing until the seal is flush with the outside face of the housing (Fig. 6). If the flywheel housing was not removed from the engine, place oil seal expander J 9769 (standard size seal) or J 21278 (oversize seal) against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the expander and on the crankshaft. Next, thread the guide studs J 9479-2 into the crankshaft. Now drive the seal into the flywheel housing with installer J 9479-1 until it is flush with the face of the housing.

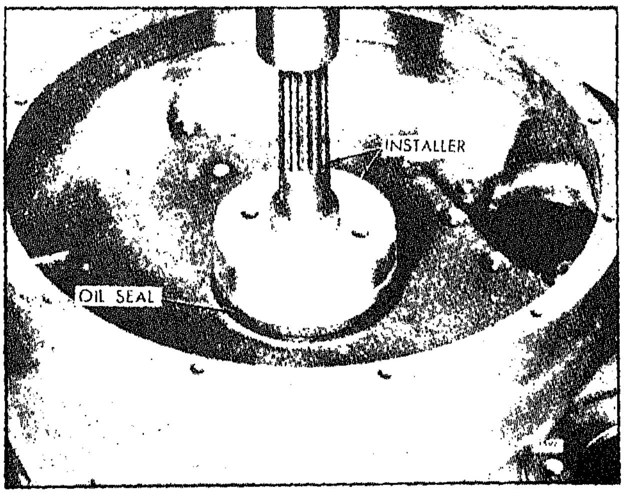


Fig. 6 - Installing Oil Seal in Flywheel Housing

6. Remove any excess sealant from the flywheel housing and the seal.

CAUTION: If the oil seal is of the type which incorporates a brass retainer in the inner diameter of the seal, be sure the retainer is in place in the seal before installing the flywheel housing on the engine. If the retainer is left out, oil leakage will result.

7. Install the flywheel housing as outlined in Section 1.5.

CRANKSHAFT MAIN BEARINGS

The crankshaft main bearing shells (Figs. 1 and 2) are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

On In-line engines, a 7/16" oil hole in the groove of each upper bearing shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

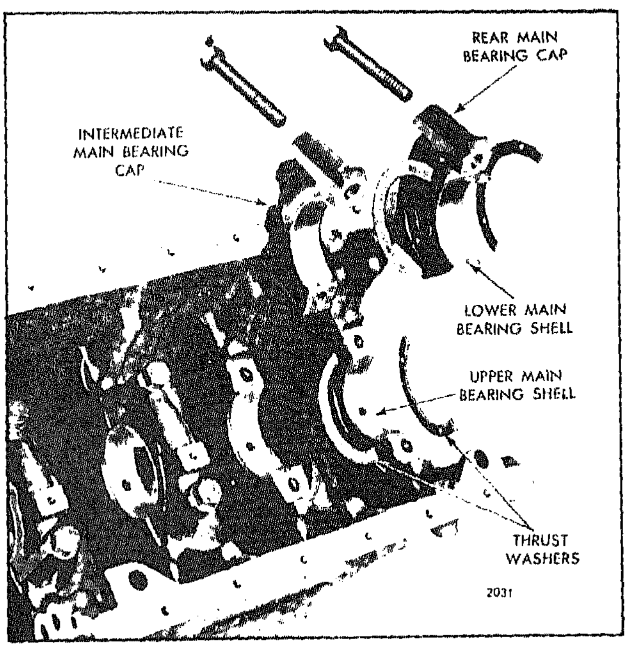


Fig. 1 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers -- In-Line Engines

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells must not be interchanged.

Thrust washers (Fig . 1) on each side of the rear main bearing, absorb the crankshaft thrust. The lower halves of the two-piece washers are doweled to the bearing cap; the upper halves are not doweled.

Main bearing trouble is ordinarily indicated by low or no oil pressure. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower main bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

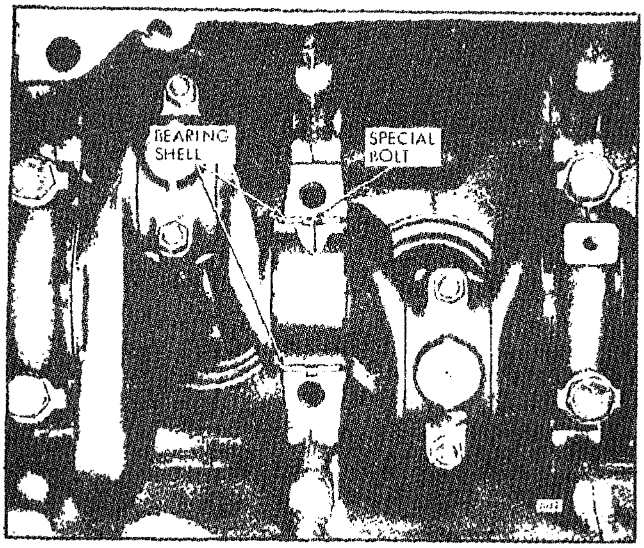


Fig. 4 - Removing Upper Main Bearing Shell (Except Rear Main)

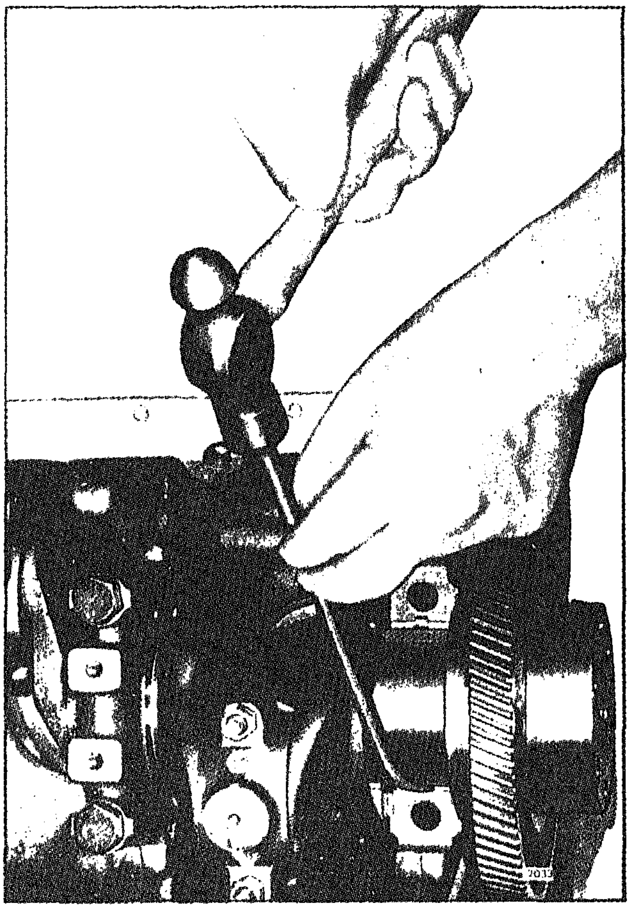


Fig. 5 - Removing Upper Rear Main Bearing Shell

Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position.

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.

2. Remove the oil pump and the oil inlet pipe and screen assembly.

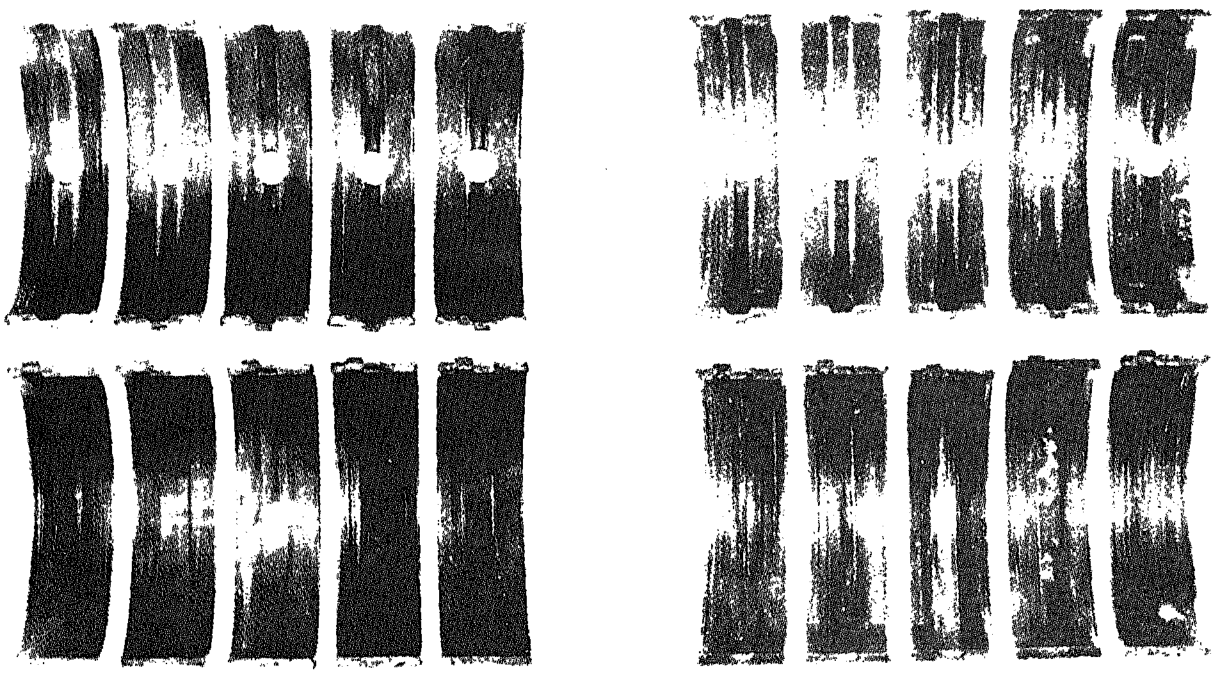


Fig. 6 - Comparison of Main Bearing Shells

3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under *Inspection*. Reinstall each bearing shell and bearing cap before removing another bearing cap.

a. To remove all except the rear main bearing shell, insert a 1/4" x 3/4" bolt with a 1/2" diameter and 1/16" thick head (made from a standard bolt) into the crankshaft journal oil hole. Then revolve the shaft to the right (clockwise) and roll the bearing shell out of position as shown in Fig. 4. The head of the bolt must not extend beyond the outside diameter of the bearing shell.

b. Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out as shown in Fig. 5.

c. The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and replace them if necessary. Also check the oil by-pass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating (Fig. 6). The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point "C", 90° from the parting line, as shown in Figs. 7 and 8. Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement.

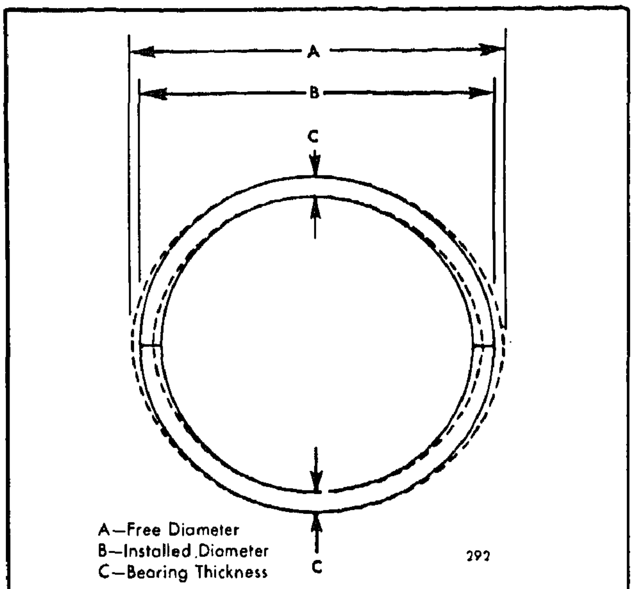


Fig. 7 - Main Bearing Measurements

The bearing shell thickness will be the total thickness of the steel ball and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The miminum thickness of a worn standard main bearing shell is .1230" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1245" to .1250" (in-line engine). Refer to Table 1.

In addition to the thickness measurement, check the

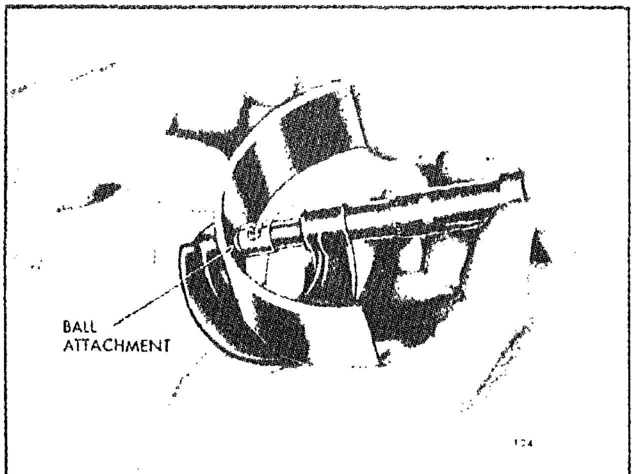


Fig. 8 - Measuring Thickness of Bearing Shell

Bearing Size	Bearing Thickness	Minimum Thickness
In-Line Engines		
Standard	.1245"/.1250"	.1230"
:002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"

TABLE 1

clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are .001" larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This *crush* assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform seat contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds .0060", all of the bearing shells must be discarded and replaced. This clearance is .0010" to .0040" with new parts.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the

crankshaft. See Section 1.3 under *Crankshaft Inspection* for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3.

Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

NOTE: Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Inspect the crankshaft thrust washers. If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to *Install Crankshaft* in Section 1.3. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1190" to .1220" thick. Thrust washers are available in .005" and .010" oversize.

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then apply clean engine oil to each crankshaft journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

The upper and lower main bearing shells are not alike; the upper shell is grooved and drilled for lubrication -- the lower shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper

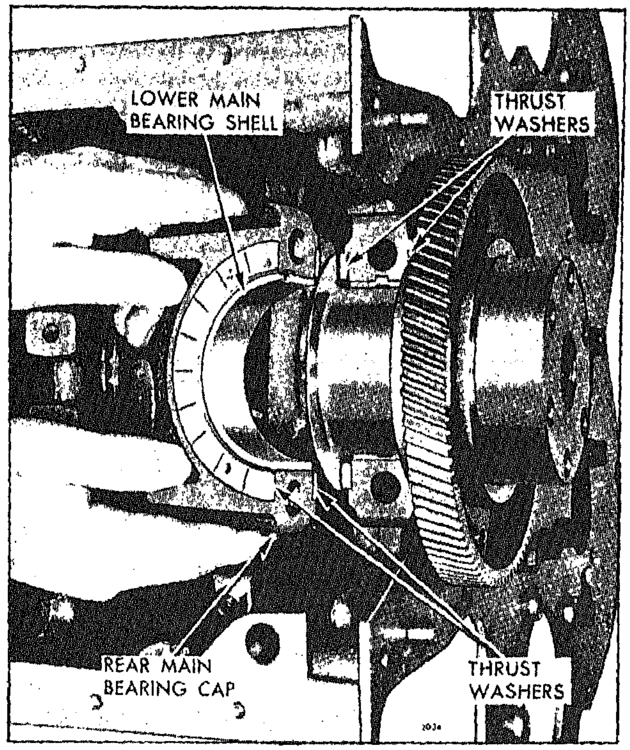


Fig. 9 - Crankshaft Thrust Washers in Place

end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.

2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

3. Assemble the crankshaft thrust washers (Fig. 9) before installing the rear main bearing cap. Clean both halves of each thrust washer carefully and remove any burrs from the washer seats -- the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then assemble the lower halves over the dowel pins in the bearing cap.

NOTE: The main bearing caps are bored in position and marked 1, 2, 3, etc. They must be installed in their original positions with the marked side of each cap facing the same side of the cylinder block that carries the engine serial number.

4. With the lower main bearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact area. Install the bearing caps and draw the bolts up snug. Then rap the caps sharply with a soft hammer to seat them properly and tighten the bolts uniformly, starting with the center bearing cap and working alternately towards both ends of the block, to 120-130 lb-ft torque.

NOTE: If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

5. Check the crankshaft end play as outlined under *Install Crankshaft* in Section 1.3.

6. Install the lubricating oil pump and oil intake pipe assembly.

NOTE: If shims were used between the pump (8V engine) and the bearing caps, install them in their original positions.

7. Install the oil pan, using a new gasket.

8. Fill the crankcase to the proper level on the dipstick with *heavy-duty* lubricating oil of the recommended grade and viscosity (refer to *Lubricating Oil Specifications* in Section 13.3).

9. After installing new bearing shells, operate the engine on a run-in schedule as outlined in Section 13.2.1.

ENGINE FRONT COVER (Lower)

In-Line Engines

The engine lower front cover is mounted against the cylinder block at the lower front end of the engine (Fig. 1). It serves as a housing for the crankshaft front oil seal, the lubricating oil pump, the oil pressure regulator valve and the oil cooler by-pass valve. The clean-out openings in the periphery of the current cover incorporate tapped holes and 1/2"-14 threaded plugs.

On all In-line engines effective with engine serial number 3D-4295 (except 3D-4373), the oil pressure regulator valve is located on the right-hand side of the engine front cover, as viewed from the front of the engine. Prior to the above engine serial numbers, the oil pressure regulator valve was located on the left-hand side of the front cover just below the oil cooler by-pass valve.

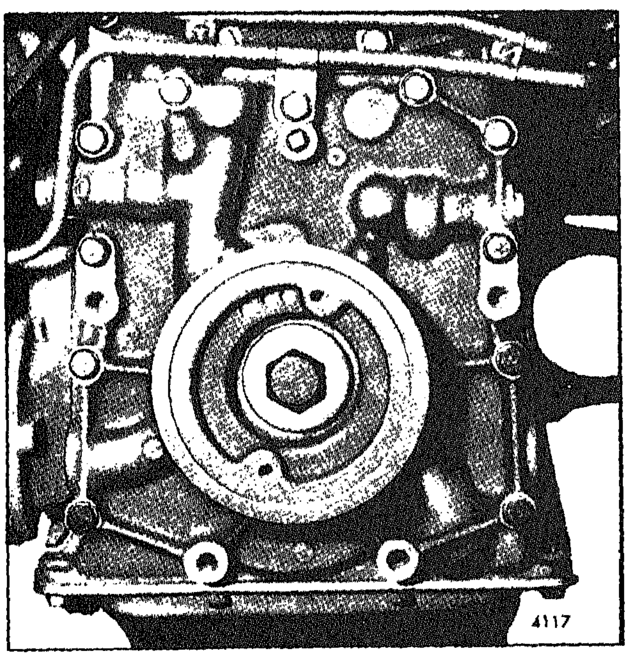


Fig. 1 - Engine Front Cover Mounting (Lower) -- In-Line Engine

Remove Engine Front Cover

1. Drain the oil and remove the oil pan.

2. Remove the crankshaft pulley as outlined in Section 1.3.7.

3. Remove the two bolts and lock washers that secure the lubricating oil pump inlet tube flange or elbow to the engine front cover.

4. Remove the bolts and lock washers that secure the engine front cover to the cylinder block.

5. Strike the cover with a soft hammer to free it from the dowels. Pull the cover straight off the end of the crankshaft.

6. Remove the cover gasket.

7. Inspect the oil seal and lubricating oil pump as outlined in Sections 1.3.2 and 4.1. Also check the oil pressure regulator valve and oil cooler by-pass valve as outlined in Sections 4.1.1 and 4.4.

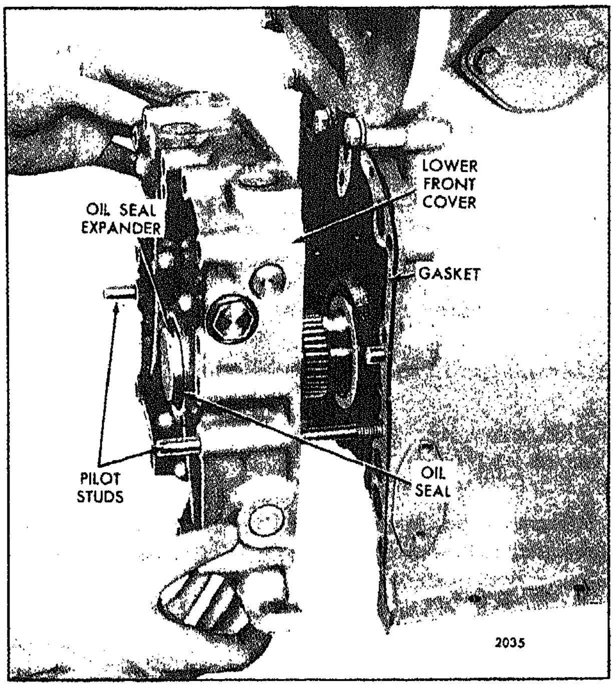


Fig. 3 - Installing Lower Engine Front Cover -- In-Line Engine

Install Engine Front Cover

1. Affix a new cover gasket to the cylinder block.

2. Install oil seal expander J 7454 over the front end of the crankshaft.

3. Thread two 3/8 ''-16 pilot studs approximately 8 '' long into two diametrically opposite bolt holes in the cylinder block to guide the cover in place (Fig. 3).

4. Apply a light coat of cup grease to the lip of the oil seal. Slide the engine front cover over the oil seal expander and pilot studs as shown in Fig. 3. Push the cover forward until the inner rotor of the oil pump contacts the pump drive gear on the crankshaft. Rotate the crankshaft slightly to align the teeth, then push the cover up against the gasket and block. Do not force the cover.

5. Remove the oil seal expander and pilot studs.

6. Refer to Fig . 1 and install the 3/8 ''-16 bolts and lock washers. Tighten the bolts to 30-35 lb-ft torque.

7. Affix a new seal ring on the end of the lubricating oil pump inlet tube next to the flange on an In-line engine.
Attach the flange or elbow to the front cover with bolts and lock washers. Tighten the bolts to 13-17 lb-ft torque.

8. Affix a new oil pan gasket to the bottom of the cylinder block, then install and secure the oil pan to the block with bolts and lock washers. Tighten the bolts to 13-17 lb-ft torque.

9. Install the crankshaft pulley as outlined in Section 1.3.7.

10. Refer to *Lubricating Oil Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

CRANKSHAFT PULLEY

The crankshaft pulley is secured to the front end of the crankshaft by a special washer and a bolt.

Remove Crankshaft Pulley

1. Remove the belts from the crankshaft pulley.

2. Remove the crankshaft pulley retaining bolt and special washer.

3. If a rigid type pulley is being removed from an In-line engine, install the pulley retaining bolt and puller J 4794-01 as shown in Fig. 1. Then force the pulley off the crankshaft by turning the puller center screw in.

On pulleys that do not incorporate two tapped holes in the front face of the pulley, use a two arm universal type puller.

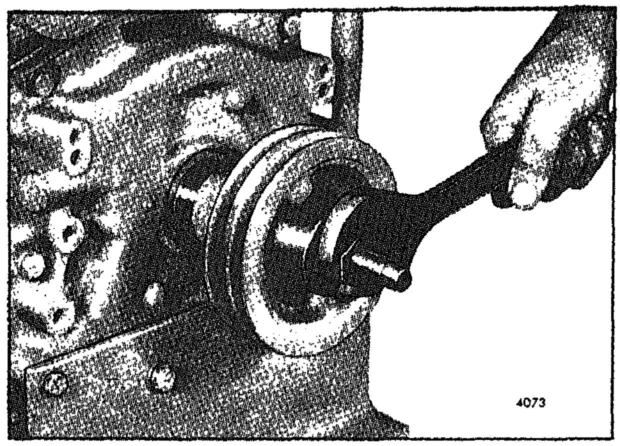


Fig. 2 - Installing Crankshaft Pulley Using Installer J 7773

4. Remove the outer and inner cones, if used.

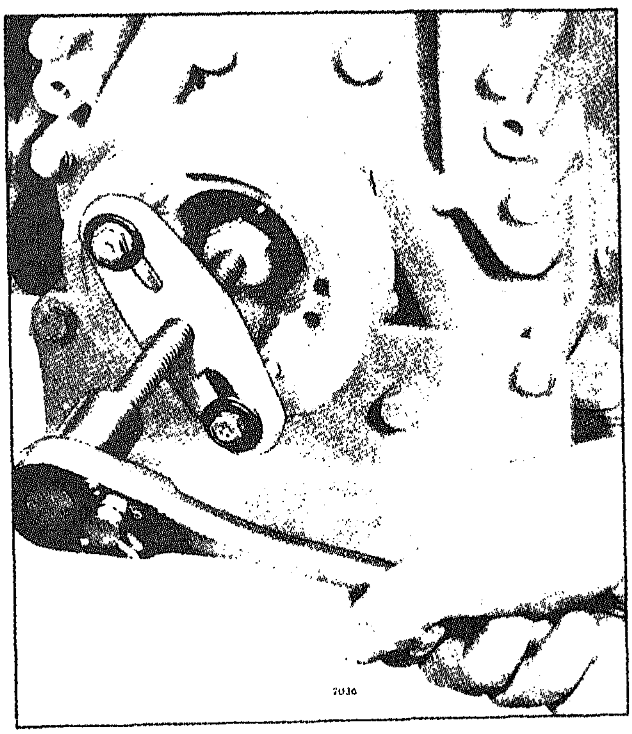


Fig. 1 - Removing Crankshaft Pulley Using Puller J 4794-01

Inspection

The appearance of the rubber bushing does not determine the condition of a rubber mounted crankshaft pulley. Check for failure of the rubber bushing by locking the crankshaft and applying pressure to the crankshaft pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the rubber bushing.

Install Crankshaft Pulley

1. Lubricate the end of the crankshaft to facilitate pulley installation.

2. Slide the inner cone (Fig. 3), if used, on the crankshaft.

4. Start the pulley straight on the end of the crankshaft.

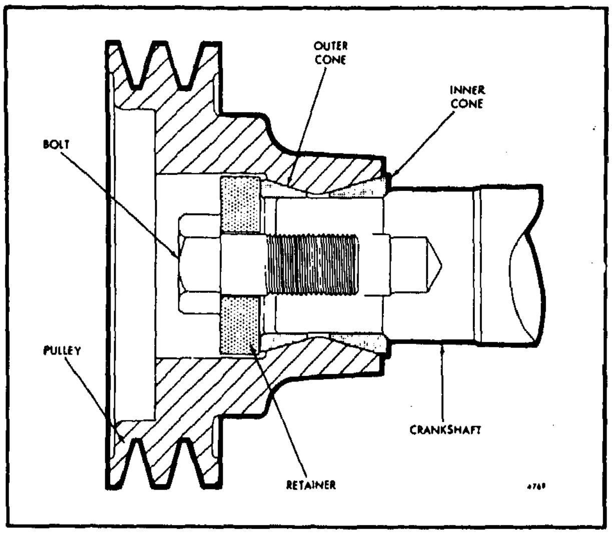


Fig. 3 - Cone Mounted Pulley

5. Install a rigid type pulley on an In-line engine with installer J 7773 as shown in Fig. 2. Then remove the installer.

7. Slide the outer cone (Fig. 3), if used, on the crankshaft.

8. Place the washer on the crankshaft bolt and thread the bolt into the front end of the crankshaft.

10. On in-line engines with cone mounted pulleys NOT stamped with the letter "A", tighten the 3/4 "-16 bolt to 290-300 lb-ft torque.

11. On all in-line engines with the rigid type pulleys and cone mounted pulleys stamped with the letter "A", tighten the 3/4 "-16 bolt to 200-220 lb-ft torque.

12. When pulleys stamped with the letter "U" (in a square box) are used, tighten the 3/4 "-16 bolt to 290-310 lb-ft torque.

14. Install and adjust the belts.

FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with six self-locking bolts.

A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

The flywheel is machined to provide true alignment with the clutch or a power take-off driving ring, and the center bore provides for installation of a clutch pilot bearing. The clutch or power take-off driving ring is bolted to the flywheel.

An oil seal ring, which provides an oil tight connection between the crankshaft and the flywheel, is fitted into a groove on flywheels used with hydraulic couplings, clutches or Torqmatic converters.

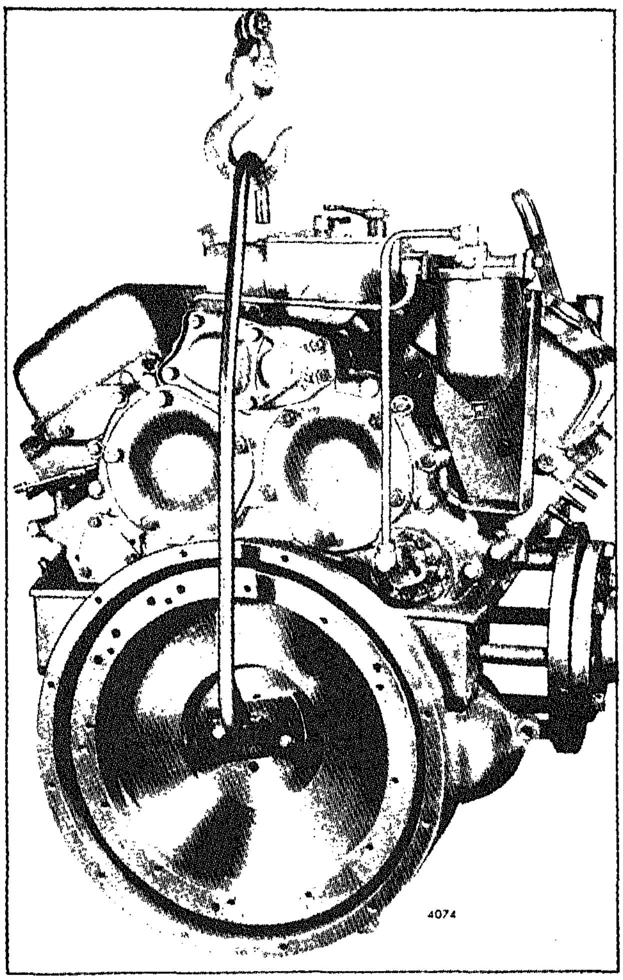


Fig. 1 - Removing Flywheel

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing. On torque converter units, the flywheel is part of the torque converter assembly and is covered in the applicable converter service manual.

Remove Flywheel (Transmission Removed)

1. If a clutch housing is attached to the flywheel housing, remove the flywheel as follows:

   a. Remove the flywheel attaching bolts and the scuff plate.

   b. Lift the flywheel off the end of the crankshaft and out of the clutch housing.

2. If a clutch housing isn't used, remove the flywheel as follows:

   a. Remove the flywheel attaching bolts and the scuff plate while holding the flywheel in position by hand, then reinstall one bolt.

   CAUTION: When removing or installing the attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft.

   b. Attach flywheel lifting tool J 6361-01 to the flywheel with two 3/8″-16 bolts of suitable length as shown in Fig. 1.

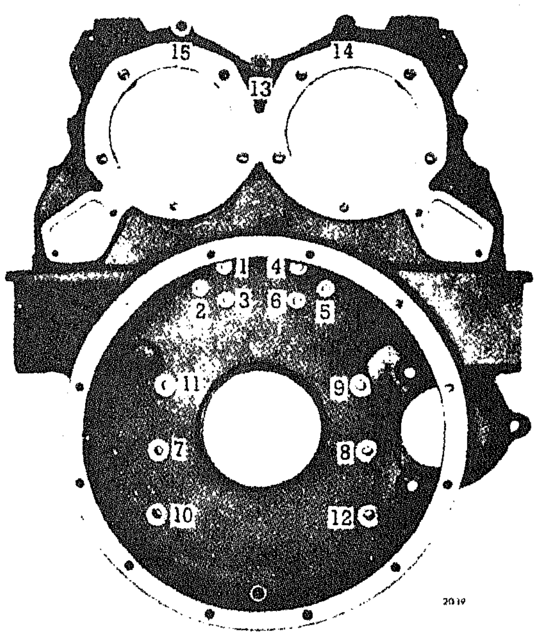
   c. Attach a chain hoist to the lifting tool.

   d. Remove the remaining flywheel attaching bolt.

   e. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.

   f. Remove the clutch pilot bearing, if used, as outlined in Section 1.4.1.

   g. Remove the oil seal ring, if used.



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x7/8"	1-2-4-5
3/8"-16x2 1/2"	7-8-9-10-11-12
3/8"-24x3 9/16"	13-14-15

Fig. 3 - Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1)--In-Line Engine

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the end plate, otherwise run-out of the pilot and face of the housing may be affected when the housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined in Section 1.3.2.

Install Flywheel Housing

1. Lubricate the gear train teeth with clean engine oil.

2. Affix a new flywheel housing gasket to the rear face of the cylinder block rear end plate.

3. If the flywheel housing has an integral cast hub, install a flywheel housing-to-end plate shim (.015 " thick). Use grease to hold the shim to the cylinder block rear end plate (Fig. 2).

4. Coat the lip of the crankshaft oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

5. Thread two pilot studs J 7540 into the cylinder block to guide the housing in place (Fig. 1). On In-line engines, to pilot the oil seal on the crankshaft successfully, use oil seal expander J 9769 (standard size seal) or J 21278 (oversize seal) on the end of the crankshaft.

6. With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket(s). Remove the oil seal expander.

7. Install all of the flywheel housing bolts, lock washers, flat washers and copper washers in their proper location, finger tight. Remove the pilot studs.

NOTE: If the engine is equipped with a clutch

housing, do not install the six bolts numbered 7 through 12 (Fig. 3) until the clutch housing is installed.

8. On an In-line right hand rotation engine, start at No. 1 and draw the bolts up snug in the sequence shown in Fig. 3.

9. Refer to Fig. 6 for the final bolt tightening sequence on an In-line engine. Then start at No. 1 and tighten the bolts to the specified torque.

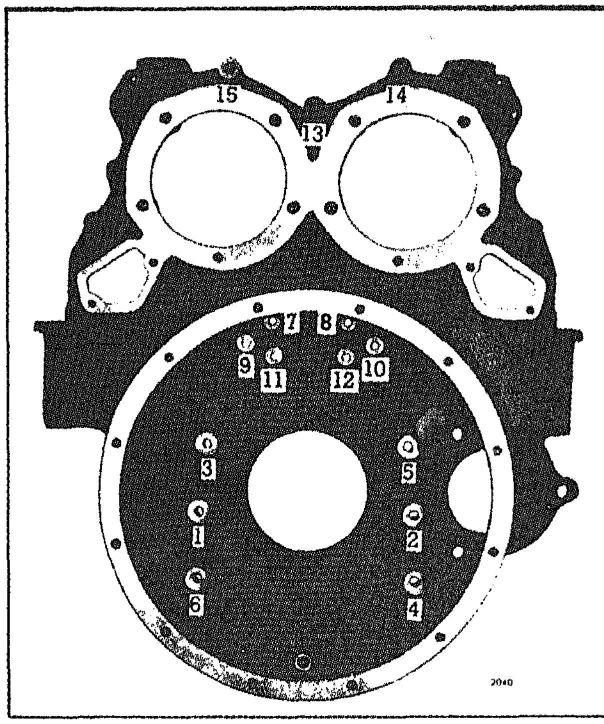


Fig. 6 - Flywheel Housing Bolt Tightening Sequence (Operation 2)--In-Line Engine

a. Tighten the 5/16"-18 bolts (numbers 11 and 12) to 19-23 lb-ft torque and the 3/8"-16 bolts (numbers 7 through 10) to 40-45 lb-ft torque. Tighten the remaining 3/8"-16 and 3/8"-24 bolts to 25-30 lb-ft torque.

NOTE: Prior to Engine Serial Number 3D-011 the bolts numbered 7 through 12 in Fig. 3 were all 5/16"-18 bolts and must be tightened to 19-23 lb-ft torque.

b. On the three cylinder engines, tighten the two 5/16"-18 bolts that secure the top of the governor to the flywheel housing to 10-12 lb-ft torque.

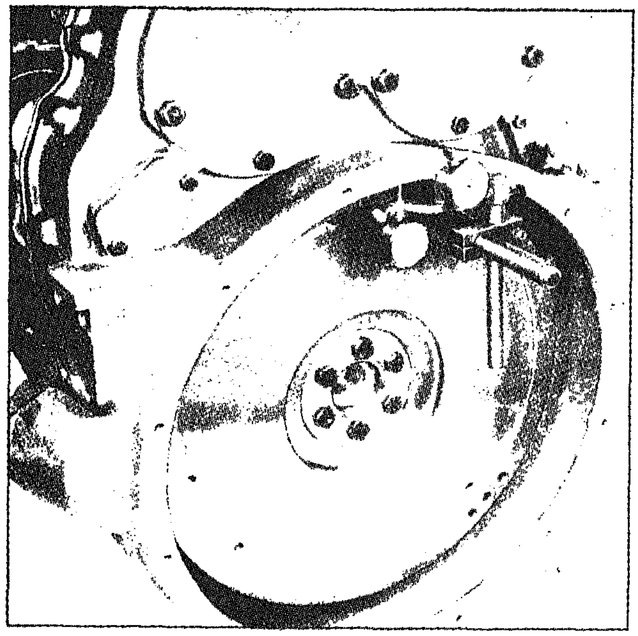


Fig. 9 · Checking Flywheel Housing Concentricity

12. Install the flywheel (Section 1.4).

13. Check the flywheel housing concentricity and bolting flange face with tool J 9737-01 as follows:

a. Refer to Fig. 9 and thread the base post J 9737-3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post.

b. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

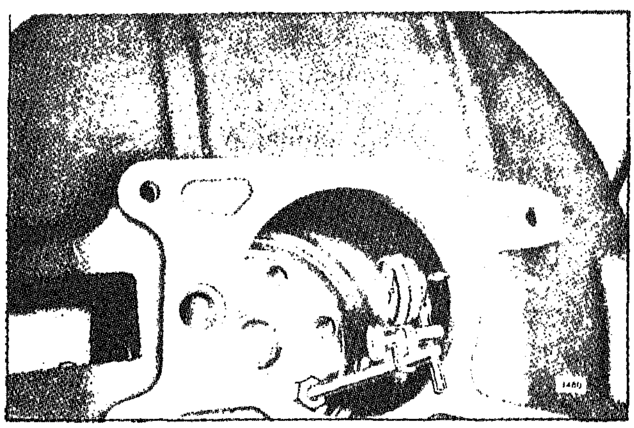


Fig. 10 · Checking Bore Runout

NOTE: If the flywheel extends beyond the housing bell, the bore and face must be checked separately. Use the special adaptor in the tool set to check the housing bore.

c. Tap the front end of the crankshaft with a soft hammer or pry it toward one end of the block to ensure end play is in one direction only.

d. Adjust each dial indicator to read zero at the twelve o'clock position. Then rotate the crankshaft one full revolution, taking readings at 45 ° intervals (8 readings each for the bore and the bolting flange face). Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed .013 " for either the bore or the face.

e. If the run-out exceeds the maximum limits, remove the flywheel housing and check for dirt or foreign material (such as old gasket material) between the flywheel housing and the end plate and between the end plate and the cylinder block.

f. Reinstall the flywheel housing and the flywheel and tighten the attaching bolts in the proper sequence and to the specified torque. Then recheck the run-out. If necessary, replace the flywheel housing.

14. Install the clutch housing, if used. Tighten the 3/8 "-16 attaching bolts to 30-35 lb-ft torque and the 3/8 "-24 nuts to 35-39 lb-ft torque.

a. Install tool J 9748 in one of the crankshaft bolt holes.

b. Install the dial indicator J 8001-3 and position it to read the bore run-out of the housing (Fig. 10). Now check the run-out by rotating the crankshaft. The run-out should not exceed .008 ".

c. Reposition the dial indicator to read the face run-out and rotate the crankshaft. The maximum allowable run-out is .008 ".

d. If the bore or face run-out is excessive, loosen the housing attaching bolts and nuts slightly and tap the housing with a soft hammer in the required direction until the run-out is within limits. Tighten the attaching bolts and nuts evenly to 30-35 and 35-39 lb-ft torque respectively. Then recheck the run-out.

16. Use a new gasket and install the oil pan.

Install and tighten the 1/2 "-13 reinforcement bolts.

17. Remove the engine from the overhaul stand and complete assembly of the engine.

PISTON AND PISTON RINGS

The trunk type malleable iron piston (Fig. 1) is plated with a protective coating of tin which permits close fitting, reduces scuffing and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress the air into close proximity to the fuel spray.

Each piston is internally braced with fin-shaped ribs and circular struts, scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil spray to ensure better control of piston ring temperature.

The piston is cooled by a spray of lubricating oil directed at the underside of the piston head from a nozzle in the top of the connecting rod, by fresh air from the blower to the top of the piston and indirectly by the water jacket around the cylinder.

Each piston is balanced to close limits by machining a balancing rib, provided on the inside at the bottom of the piston skirt.

Two bushings, with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened, floating piston pin. After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a steel retainer. Thus lubricating oil returning from the sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

Each piston is fitted with compression rings and oil control rings (Fig. 1).

Equally spaced holes are drilled just below each oil control ring land to permit the excess oil that is scraped off the cylinder walls to return to the crankcase.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

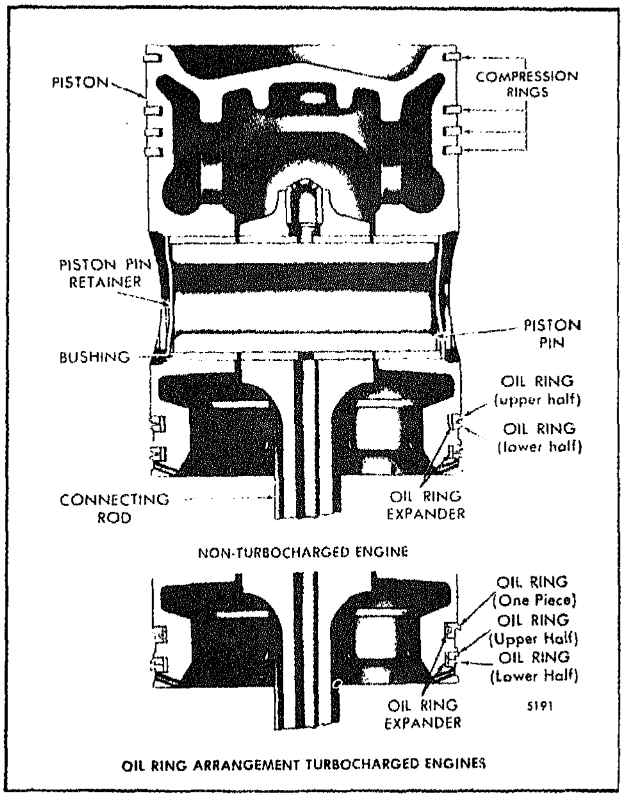


Fig. 1 - Typical Piston Assembly

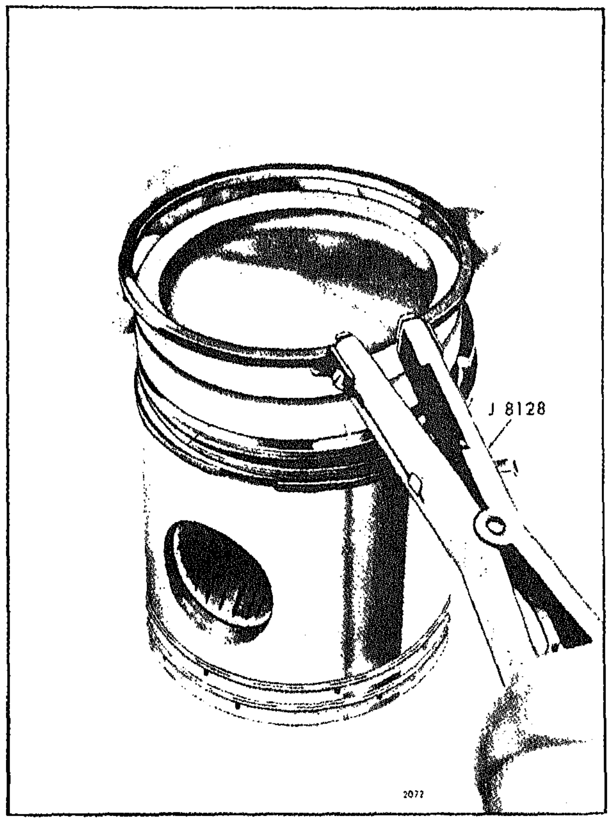


Fig. 2 - Removing or Installing Piston Ring

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.

2. Drain the oil and remove the oil pan.

3. Remove the oil pump and inlet and outlet pipes, if necessary (Section 4.1).

4. Remove the cylinder head (Section 1.2).

5. Remove the carbon deposits from the upper inner surface of the cylinder liner.

6. Use a ridge cutter to remove any ridge in the cylinder liner at the top of the piston ring travel.

> **NOTE:** Move the piston to the bottom of its travel and place a cloth over the top of the piston to collect the cuttings. After the ridge has been removed, turn the crankshaft to bring the piston to the top of its stroke and carefully remove the cloth with the cuttings.

7. Remove the bearing cap and the lower bearing shell from the connecting rod. Then push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.

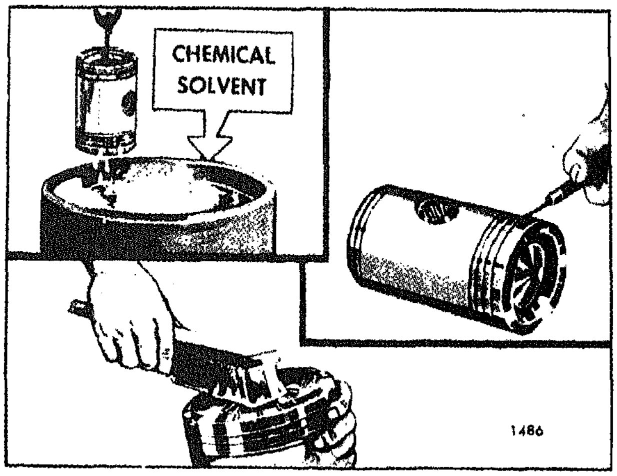


Fig. 3 - Cleaning Piston

8. Reassemble the bearing cap and lower bearing shell to the connecting rod.

Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then remove the rings and connecting rod from the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 as shown in Fig. 2.

2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushings.

3. Withdraw the piston pin from the piston, then remove the connecting rod.

4. Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

Clean Piston

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits, use a chemical solvent (Fig. 3) that will not harm the piston pin bushings or the tin-plate on the piston.

The upper part of the piston, including the compression ring lands and grooves, is not tin-plated and may be wire-brushed to remove any hard carbon. However, use care to avoid damage to the tin-plating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston and the oil drain holes in the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

Inspection

If the tin-plate on the piston and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored pistons, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material

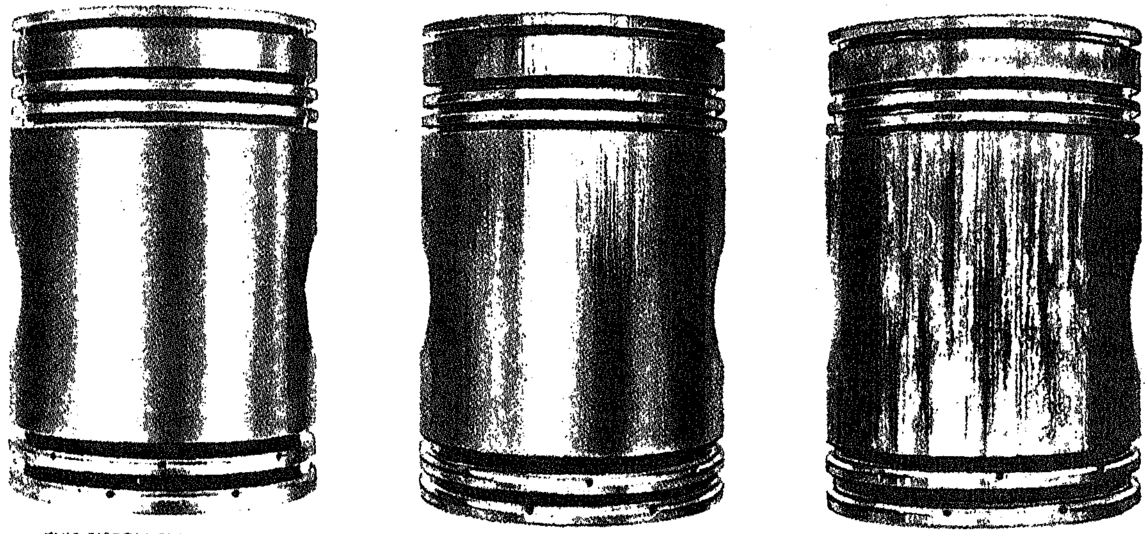


Fig. 4 · Comparison of Pistons

introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which may be cleaned up may be re-used (Fig. 4). Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage.

Replace the piston if cracks are found across the internal struts. Use the magnetic particle inspection methods outlined in Section 1.3 under *Crankshaft Inspection* for locating cracks in the piston.

Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to Section 1.0 for specifications).

Inspection of the connecting rod and piston pin are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakge into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

Inspect and measure the piston pin bushings. The piston pin-to-bushing clearance with new parts is .0025" to .0034". A maximum clearance of .010" is allowable with worn parts. The piston pin bushings in the connecting rod are covered in Section 1.6.1.

Remove Bushings from Piston

1. Place the piston in the holding fixture J 1513-1 so that the bushing bores are in alignment with the hole in the fixture base.

2. Drive each bushing from the piston with the bushing remover J 4972-4 and handle J 1513-2 (Fig. 5).

Install Bushings in Piston

1. Place the spacer J 7587-1 in the counterbore in the fixture J 1513-1 (small end up).

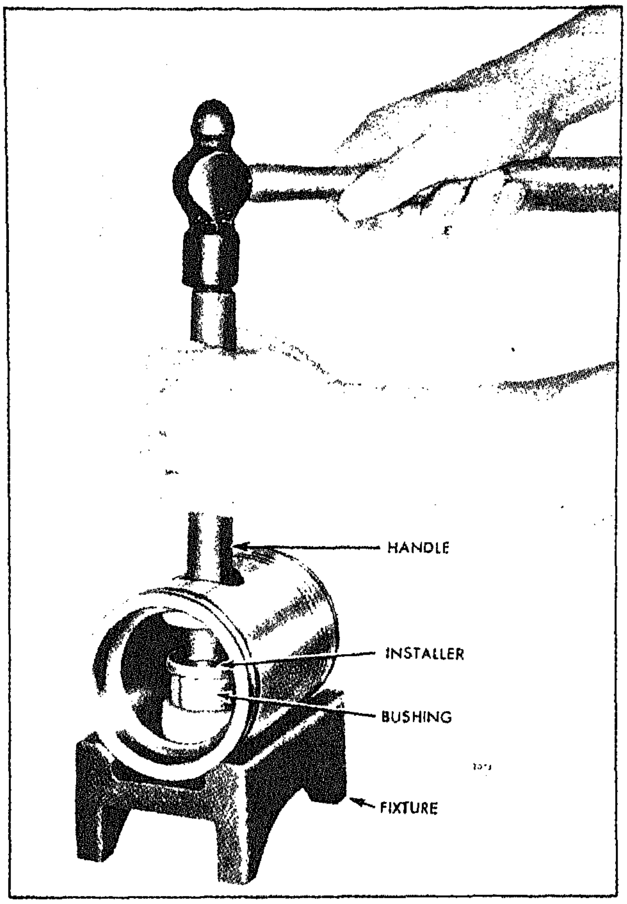


Fig. 5 - Removing or Installing Piston Pin Bushings

2. Place the piston on the fixture so that the spacer protrudes into the bushing bore.

3. Insert the installer J 4972-2 in a bushing, then position the bushing and installer over the lower bushing bore.

NOTE: Locate the joint in the bushing toward the bottom of the piston (Fig. 6).

4. Insert the handle J 1513-2 in the bushing installer and drive the bushing in until it bottoms on the spacer.

5. Install the second bushing in the same manner.

6. The bushings must withstand an end load of 1800 pounds without moving after installation.

7. Ream the bushings to size as follows:

a. Clamp the reaming fixture J 5273 in a vise

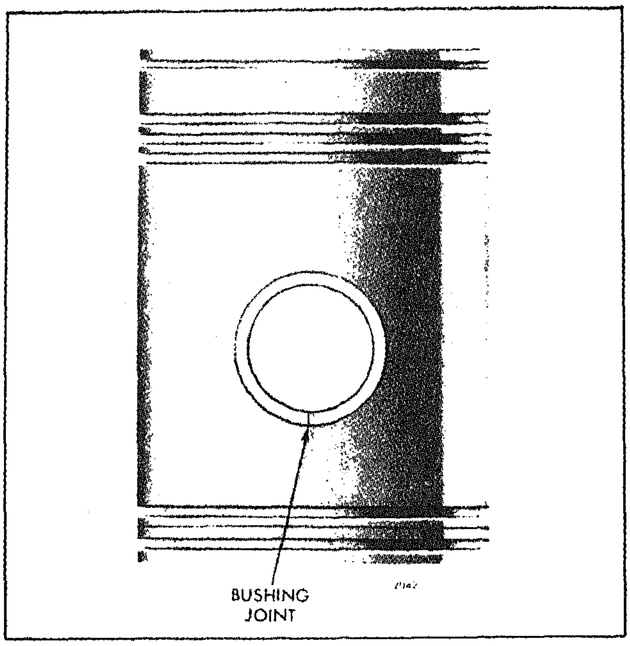


Fig. 6 - Location of Joint in Piston Pin Bushings

(Fig. 7). Then insert the guide bushing J 4970-5 in the fixture and secure it with the set screw.

b. Place the piston in the fixture and insert the pilot end of the reamer J 4970-4 through the clamping bar, bushings and into the guide bushing.

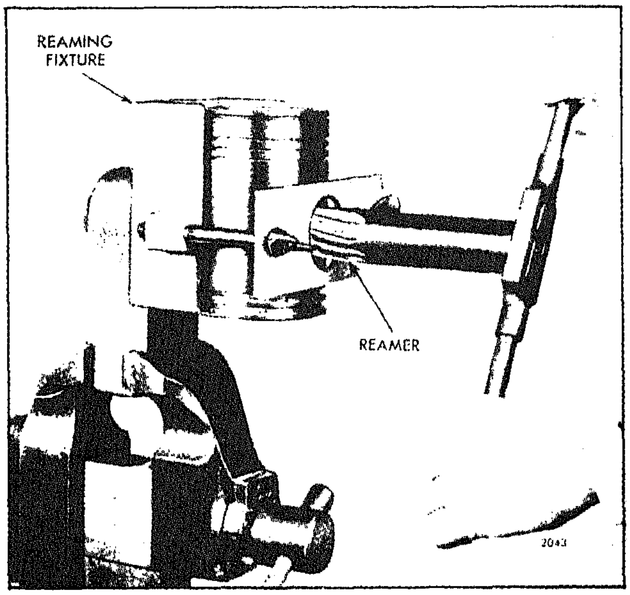


Fig. 7 - Reaming Piston Pin Bushings

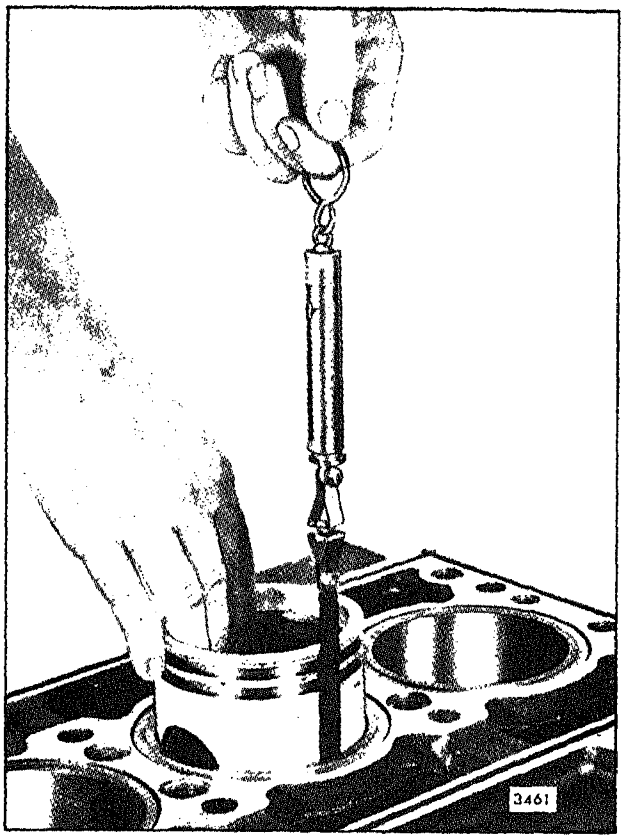


Fig. 8 - Measuring Piston-to-liner Clearance

c. With the piston, fixture and reamer in alignment, tighten the wing nuts securely.

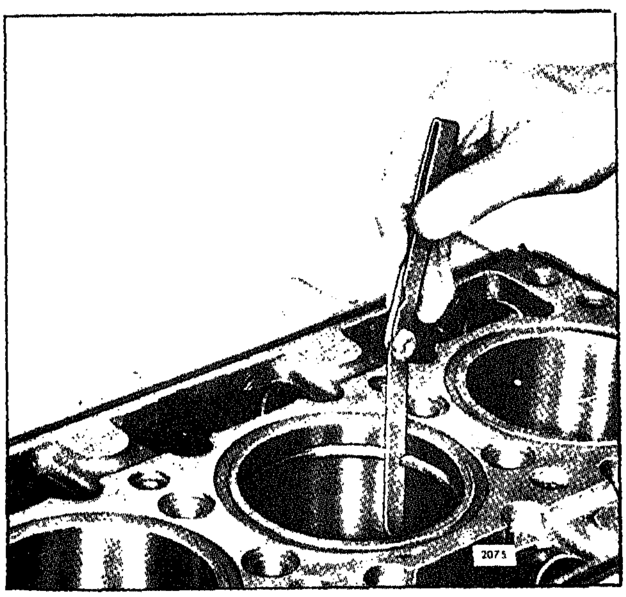


Fig. 9 - Measuring Piston Ring Gap

d. Ream the bushings (Fig. 7). Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

e. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.3775" to 1.3780".

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70° F.). The taper and out-of-round must not exceed .0005". Refer to Section 1.0 for piston diameter specifications.

A new cylinder liner has an inside diameter of 3.8752" to 3.8767". The piston-to-liner clearance, with new parts, is .0031" to .0068" (non-turbocharged engines).
A maximum clearance of .010" (non-turbocharged engines) is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston upside down in the liner and check the clearance in four places 90° apart (Fig. 8).

Use feeler gage set J 5438 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

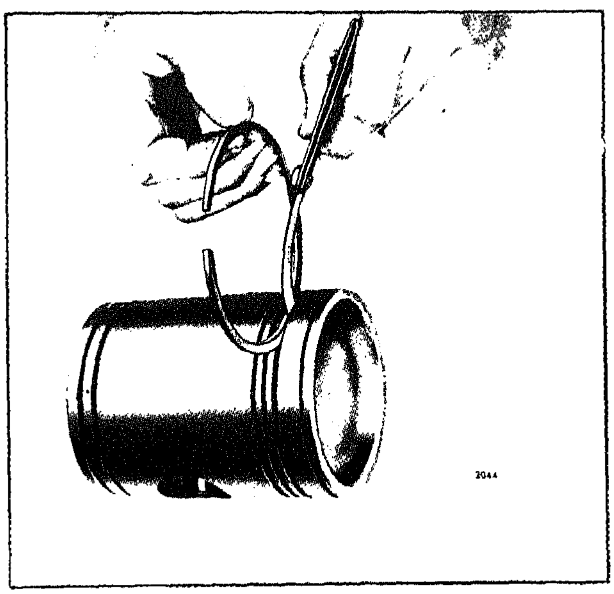


Fig. 10 - Measuring Piston Ring Side Clearance

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001" greater than the thickness of the feeler gage used, i.e., a .004" feeler gage will indicate a clearance of .005" when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, three compression rings and two oil control rings (Fig. 1).

The current top compression (fire) ring can be identified by the bright chrome on the bottom side and oxide (rust color) on the top. The former ring had a plain metal color on both sides.

A two-piece oil control ring is used in both oil ring grooves in the pistons for non-turbocharged (naturally aspirated) engines.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston to push the ring down to be sure it is parallel with the top of the liner. Then measure the ring gap with a feeler gage as shown in Fig. 9. Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015"

Check the ring side clearance as shown in Fig. 10. Ring side clearances are specified in Section 1.0.

Install Piston Rings

Before installing the piston rings, assemble the piston and rod as outlined under *Assemble Connecting Rod to Piston* in Section 1.6.1. Then refer to Fig. 1 and install the piston rings.

NOTE: Lubricate the piston rings and piston with engine oil before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 as shown in Fig. 2. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston.

CAUTION: When installing the top compression (fire) ring with the tapered face, be sure the side marked "TOP" is toward the top of the piston.

2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

The upper and lower oil control rings used on pistons for *non-turbocharged* engines consist of two halves (upper and lower).

Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston.

CAUTION: When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then install the lower half with the gap 45° from the gap in the

upper half of the ring. Make sure the scraper edges are facing down (toward the bottom of the piston).

NOTE: The scraping edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

3. Install the upper and lower halves of both oil control rings (non-turbocharged engines) as outlined above.

If there is a noticeable resistance during installation of the piston, check for an overlapped ring expander.

CONNECTING ROD

Each connecting rod (Figs. 1 and 2) is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end. The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head on engines equipped with an oil cooler. Engines that are not equipped with an oil cooler do not use nozzle type connecting rods. An orifice is pressed into a counterbore at the lower end of the oil passage (in rods equipped with a spray nozzle) to meter the flow of oil.

NOTE: Never intermix nozzle type connecting rods in an engine with non-nozzle type connecting rods.

A helically-grooved bushing is pressed into each side of the connecting rod at the upper end. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this cavity lubricates the piston pin bushings and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

A service connecting rod includes the bearing cap. bolts, nuts, spray nozzle (if used), orifice and the piston pin bushings pressed in place and bored to size.

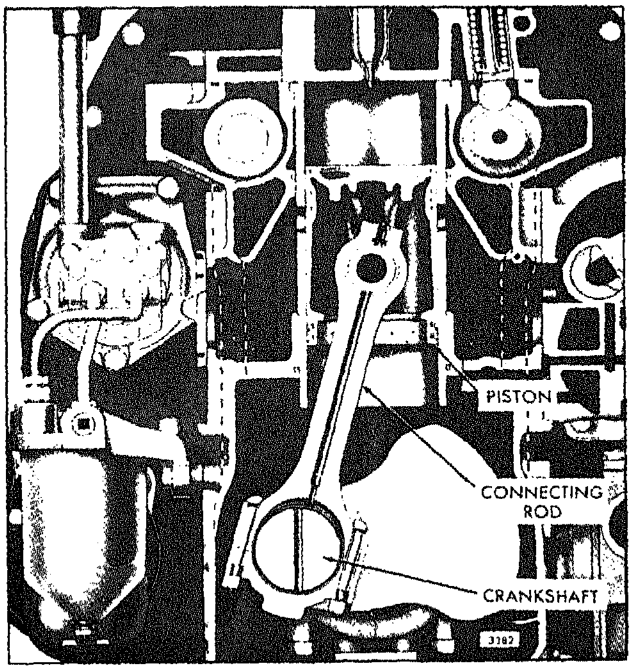


Fig. 1 - Connecting Rod Mounting

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined in Section 1.6.

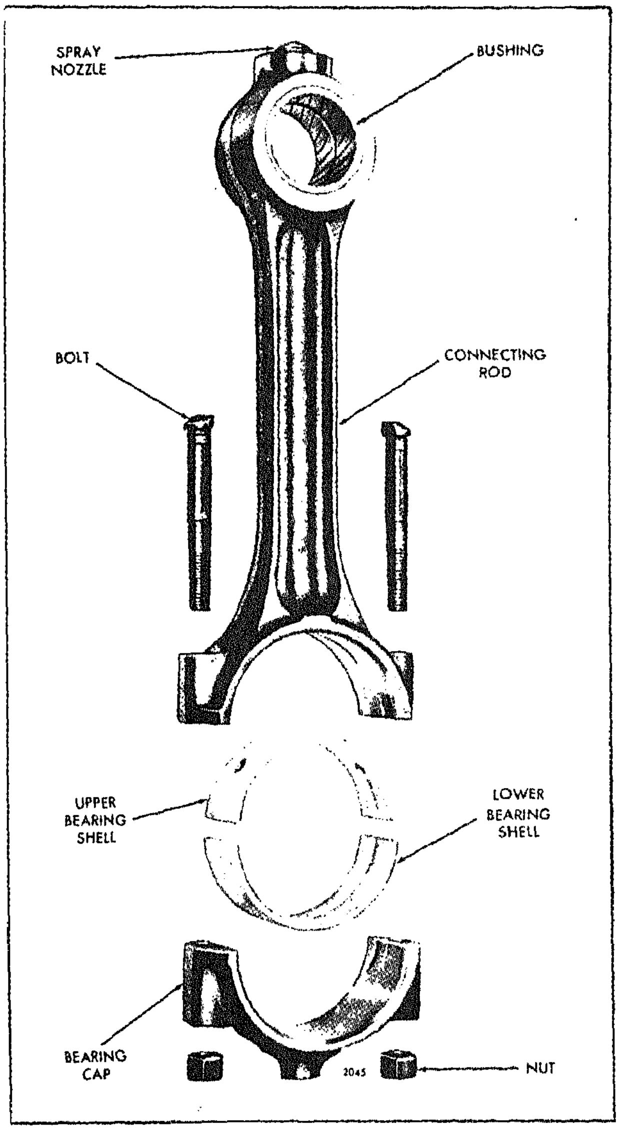


Fig. 2 - Connecting Rod Details and Relative Location of Parts

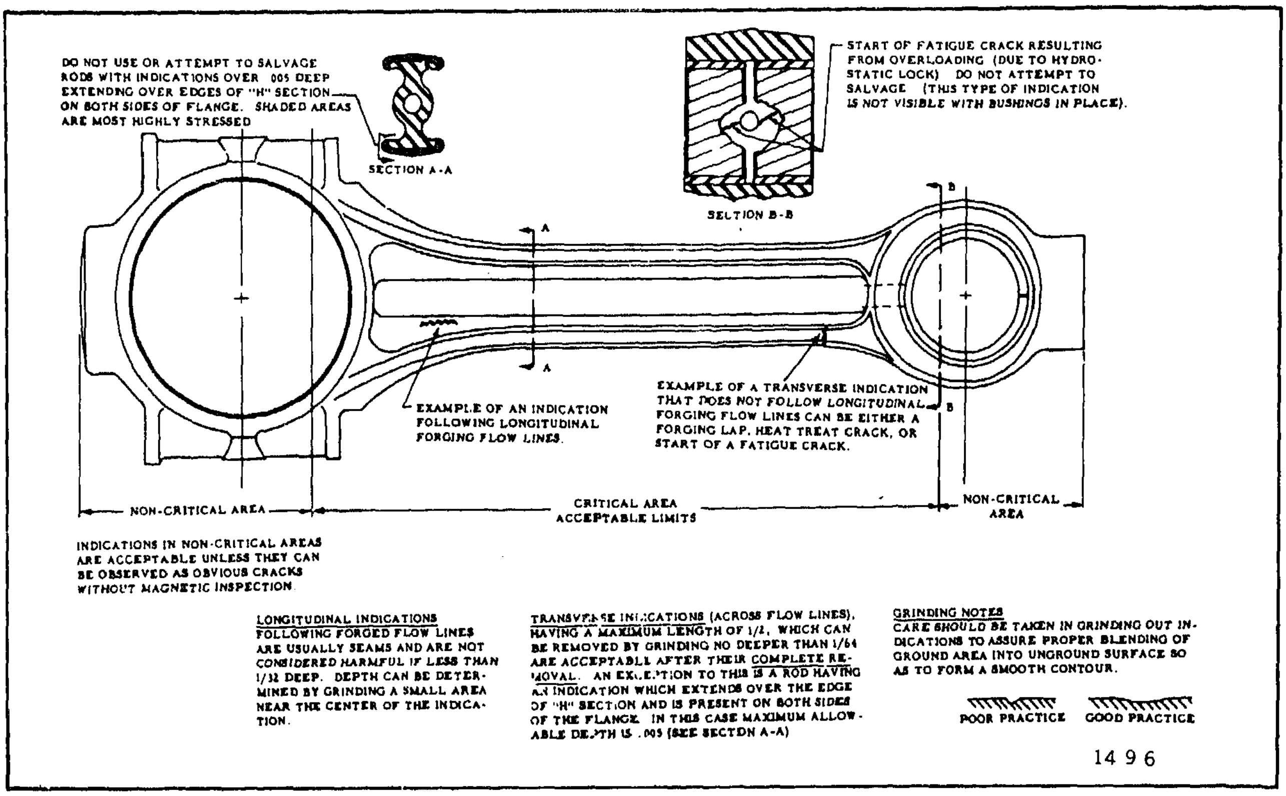


Fig. 3 - Magnetic Particle Inspection Limits for Connecting Rod

Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air. Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice, oil passage and spray holes are not clogged.

Check the connecting rod for cracks (Fig. 3) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection*.

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

> **NOTE:** Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice, oil passage and spray holes are not clogged. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Check the connecting rod bushings for indications of scoring, overheating or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the lubricating oil to the piston pin, bushings and spray nozzle.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear.

Since it is subjected to downward loading only, free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full floating fit in the connecting rod and piston bushings, with relatively large clearances. Worn piston pin clearances up to .010" are satisfactory.

Remove Bushings

If it is necessary to replace the connecting rod bushings, remove them as follows:

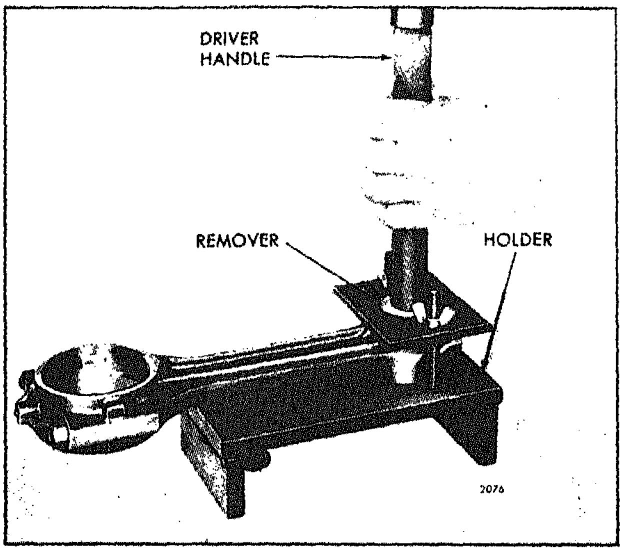


Fig. 4 · Removing or Installing Bushings

1. Clamp the upper end of the connecting rod in holder J 7632 (Fig. 4) so that the bore in the bushings is aligned with the hole in the base of the holder.

2. Place the bushing remover J 4972-4 in the connecting rod bushing, insert handle J 1513-2 in the remover and drive the bushings from the rod.

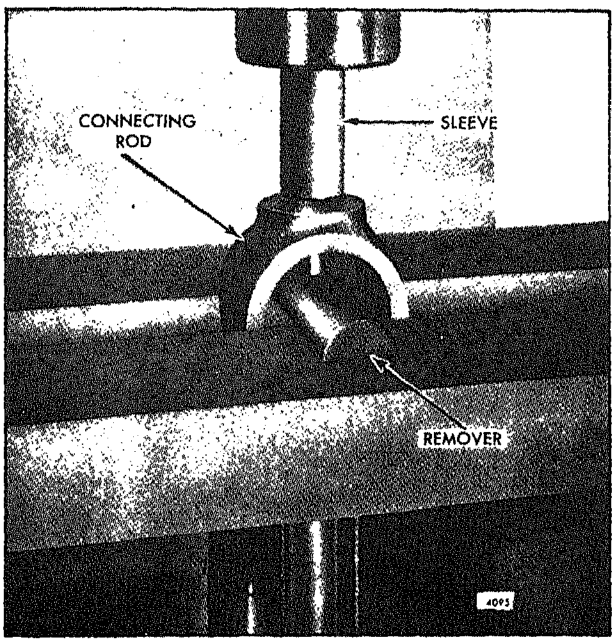


Fig. 5 · Removing Spray Nozzle

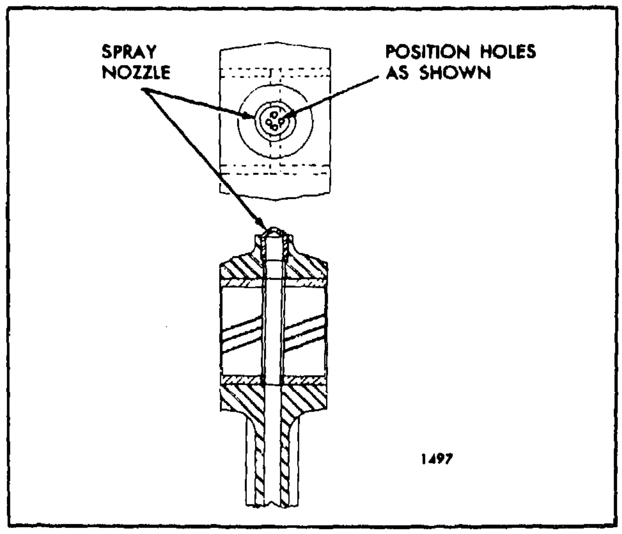


Fig. 6 · Position of Spray Nozzle Holes

Replace Spray Nozzle

The connecting rod bushings must be removed before the spray nozzle can be replaced. The orifice in the lower end of the drilled passage in the connecting rod is not serviced and it is not necessary to remove it when replacing the spray nozzle.

Replace the spray nozzle as follows:

1. Remove the connecting rod bushings (note *Caution).*

2. Insert spray nozzle remover J 8995 through the upper end of the connecting rod and insert the pin, in the curved side of the tool, in the opening in the bottom of the spray nozzle.

3. Support the connecting rod and tool in an arbor press as shown in Fig. 5.

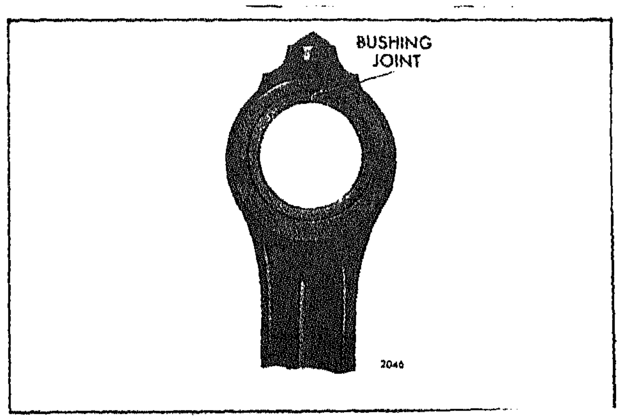


Fig. 7 · Location of Bushing Joint

4. Place a short sleeve directly over the spray nozzle. Then press the nozzle out of the connecting rod.

5. Remove the tool.

6. Start the new spray nozzle, with the holes positioned as shown in Fig. 6, straight into the counterbore in the connecting rod.

7. Support the connecting rod in the arbor press, place a short 3/8" I.D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.

8. Install new bushings in the connecting rod.

Install Bushings

1. Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings aligns with the hole in the base of the tool (Fig. 4).

2. Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Fig. 7).

3. Insert installer J 4972-2 in the bushing, then insert handle J 1513-2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.

4. Turn the connecting rod over in the holder and install the second bushing in the same manner.

5. The bushings must withstand an end load of 2000 pounds without moving after installation.

6. Ream the bushings to size as follows:

a. Clamp reaming fixture J 7608-4 in a bench vise.

c. Place the crankshaft end of the connecting rod on the arbor of the fixture (Fig. 8). Tighten the nuts on the 3/8"-24 bolts (In-line engines) to 40-45 lb-ft torque.

d. Slide the front guide bushing J 4971-6 (with the pin end facing out) in the fixture.

e. Install spacer J 7608-3 in the fixture.

f. Align the upper end of the connecting rod with the hole in the reaming fixture.

g. Install the rear guide bushing J 1686-5 on the reamer J 7608-21, then slide the reamer and bushing into the fixture.

h. Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

i. Remove the reamer and the connecting rod from the fixture, blow out the chips and measure the inside diameter of the bushings. The inside diameter of the bushings must be 1.3760" to 1.3765". This will provide a piston pin-to-bushing clearance of .0010"

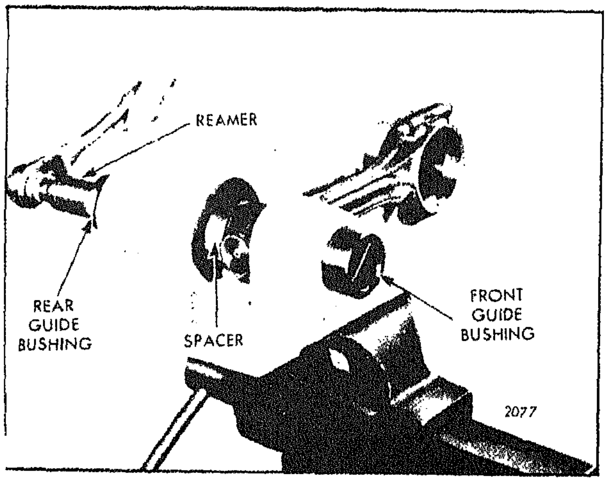


Fig. 8 - Reaming Bushings

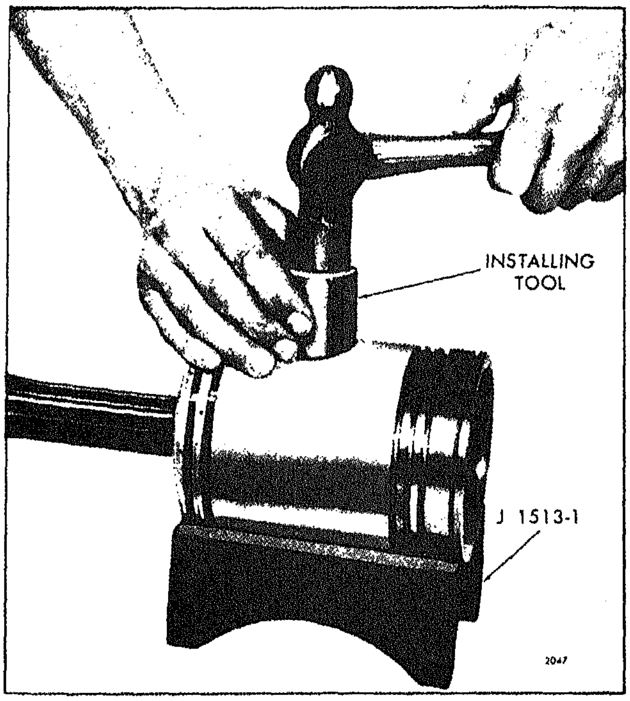


Fig. 9 - Installing Piston Pin Retainer

to .0019" with a new piston pin. A new piston pin has a diameter of 1.3746" to 1.3750".

Assemble Connecting Rod to Piston

Apply clean engine oil to the piston pin and bushings. Refer to Fig. 2 and assemble the connecting rod to the piston as follows:

1. Place the piston in the holding fixture (Fig. 9).

2. Place a new piston pin retainer in position. Then place the crowned end of installer J 23762 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston.

> **CAUTION:** Do not drive the retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.

3. Place the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then slide the piston pin in place. If the piston pin-to-bushing clearances are within the specified limits, the pin will slip into place without use of force.

4. Install the second piston pin retainer as outlined in Steps 1 and 2.

5. After the piston pin retainers have been installed, check for piston pin end clearance by *cocking* the connecting rod and shifting the pin in its bushings.

6. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushings, from reaching the cylinder walls. Check the retainers for proper sealing as follows:

a. Place the piston and connecting rod assembly upside down on a bench.

b. Pour clean fuel oil in the piston to a level above the piston pin bosses.

c. Dry the external surfaces of the piston in the area around the retainers and allow the fuel oil to set for about fifteen minutes.

d. Check for seepage of fuel oil around the retainers. If the fuel oil leaks around the retainers, install new retainers. In extreme cases, it may be necessary to replace the piston.

e. After the leakage test is completed, empty the fuel oil from the piston, dry the parts with compressed air and lubricate the piston pin with clean engine oil.

7. Install the piston rings on the piston as outlined in Section 1.6.

8. Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Fig. 1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell has two short oil grooves and two oil holes; each groove begins at the end of the bearing shell and terminates at an oil hole. The lower bearing shell has a continuous oil groove from one end of the shell to the other. These grooves maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

Remove Bearing Shells

The connecting rod bearing caps are numbered 1, 2, 3, etc. on an In-line engine with matching numbers stamped on the connecting rods. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

Remove the connecting rod bearings as follows:

1. Drain the oil and remove the oil pan.

2. Remove the oil inlet pipe and screen assembly.

3. Remove one connecting rod bearing cap. Push the connecting rod and piston assembly up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.

4. Inspect the upper and lower bearing shells as outlined under *Inspection.*

5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching or signs of overheating. If any of these defects are present, the bearings must be discarded. The upper bearing shells, which

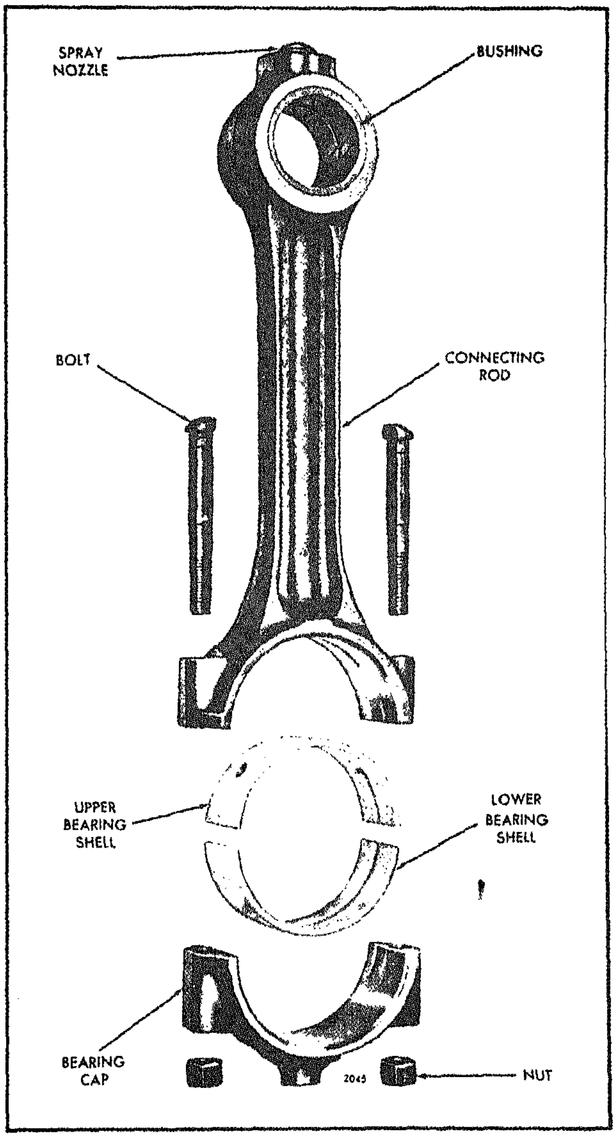


Fig. 1 - Connecting Rod and Bearing Shells

Bearing Size	Bearing Thickness	Minimum Thickness
In-Line Engines		
Standard	.1245"/.1250"	.1230"
.002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"
V-Type Engine		
Standard	.1247"/.1252"	.1230"
.002" Undersize	.1257"/.1262"	.1240"
.010" Undersize	.1297"/.1302"	.1280"
.020" Undersize	.1347"/.1352"	.1330"
.030" Undersize	.1397"/.1402"	.1380"

TABLE 1

carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under *Inspection* in Section 1.3.4. The minimum thickness of a worn standard connecting rod bearing shell should not be less than .1230" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1245" to .1250" (in-line engine). Refer to Table 1.

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). The maximum connecting rod bearing-to-journal clearance with used parts in .006".

Before installing the bearings, inspect the crankshaft journals (refer to *Inspection* in Section 1.3).

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3.

Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

NOTE: Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod in place, install the connecting rod bearings as follows:

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.

2. Install the upper bearing shell -- the one with the short groove and oil hole at each parting line -- in the connecting rod. Be sure the tang on the bearing shell fits in the groove in the connecting rod.

3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.

4. Note the numbers stamped on the connecting rod and the bearing cap and install the lower bearing shell -- the one with the continuous oil groove -- in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.

5. Install the bearing and cap and tighten the nuts on the 3/8"-24 bolts (In-line engines) to 40-45 lb-ft torque.

6. Install the lubricating oil pump inlet tube assembly. Replace the inlet tube seal ring or elbow gasket if hardened or broken.

7. Install the oil pan, using a new gasket.

8. Refer to the *Lubricating Oil Specifications* in Section 13.3 and fill the crankcase to the proper level on the dipstick.

9. If new bearings were installed, operate the engine on the run-in schedule as outlined in Section 13.2.1.

CYLINDER LINER

The cylinder liner (Fig. 1) is of the replaceable wet type, made of hardened alloy cast iron, and is a slip fit in the cylinder block. The current liner is centrifugally cast, while the former liner was sand cast.

The liner is inserted in the cylinder bore from the top of the cylinder block. The flange of each liner rests on a counterbore in the top of the block.

A synthetic rubber seal ring, recessed in the cylinder block bore, is used between the liner and the block to prevent water leakage into the air box.

The upper portion of the liner is directly cooled by water surrounding the liner. The center portion of the liner is air cooled by the scavenging air which enters the cylinder through eighteen equally spaced ports.

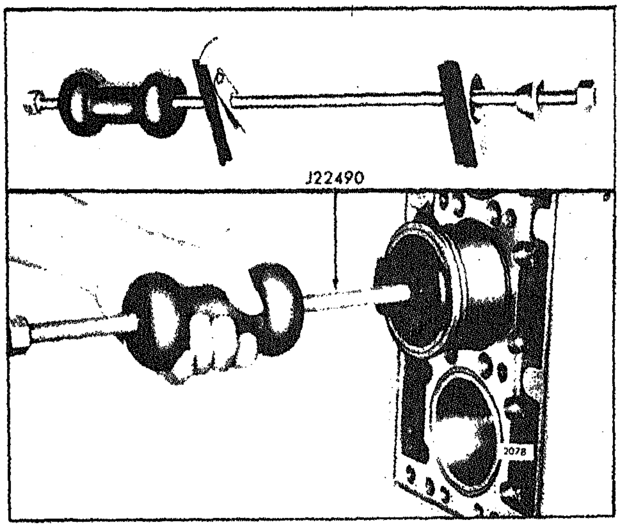


Fig. 2 - Removing Cylinder Liner

The air inlet ports in the liner are machined at an angle to create a uniform swirling motion to the air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly according to the surroundings in which the engine is operating.

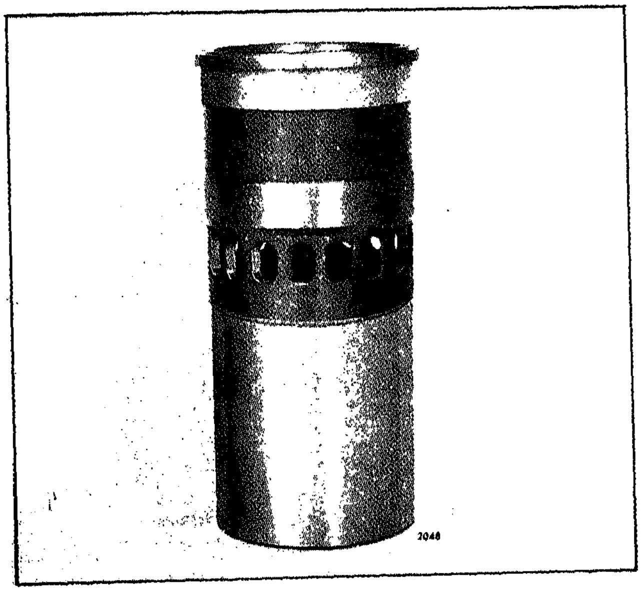


Fig. 1 - Cylinder Liner

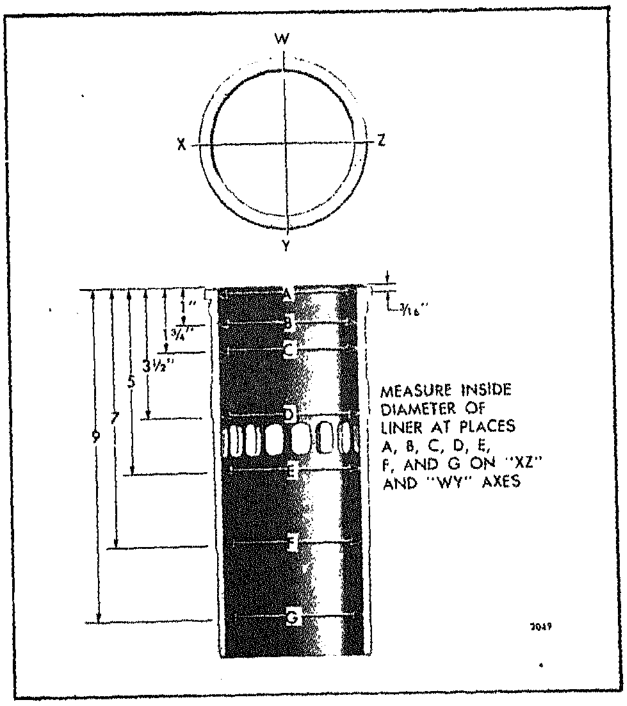


Fig. 3 - Cylinder Liner Measurement Diagram

Remove Cylinder Liner

It is very important that the proper method is followed when removing a cylinder liner. *Do not* attempt to push the liner out by inserting a bar in the liner ports and rotating the crankshaft, otherwise the piston may be damaged or the upper ring groove may collapse.

To remove a cylinder liner, refer to Fig. 2 and proceed as follows:

1. Remove the piston and connecting rod assembly as outlined in Section 1.6.

2. Remove the cylinder liner with tool set J 22490 as follows:

a. Slip the lower puller clamp up on the puller rod and off the tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back on the tapered seat after it clears the bottom of the liner. Then slide the upper puller clamp down against the top edge of the liner.

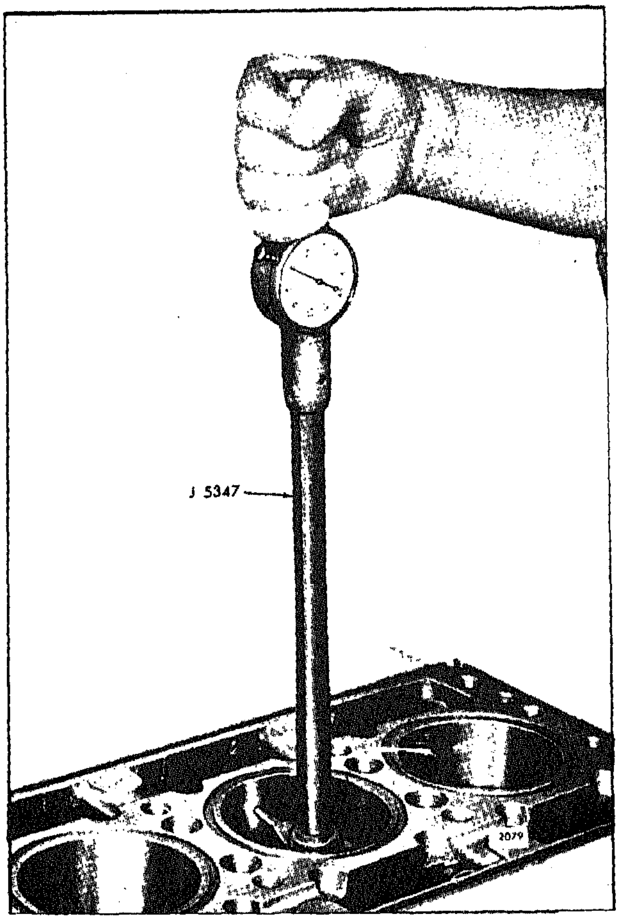


Fig. 4 · Checking Bore of Cylinder Liner

b. With the tool in place, strike the upset head on the upper end of the puller rod a sharp blow with the puller weight, thus releasing the liner.

c. Remove the tool from the liner. Then remove the liner from the cylinder block.

d. Remove and discard the cylinder liner seal ring from the groove in the cylinder block bore.

If tool J 22490 is unavailable, tap the liner out with a hardwood block and hammer.

Inspect Used Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

Cracks
Scoring
Poor contact on outer surface
Flange irregularities
Inside diameter
Out-of-round
Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned-up and re-used.

Excessive liner-to-block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant. Poor contact between the liner and the block bore may be indicated by stains or low pressure areas on the outer surface of the liner.

Examine the outside diameter of the liner for fretting.

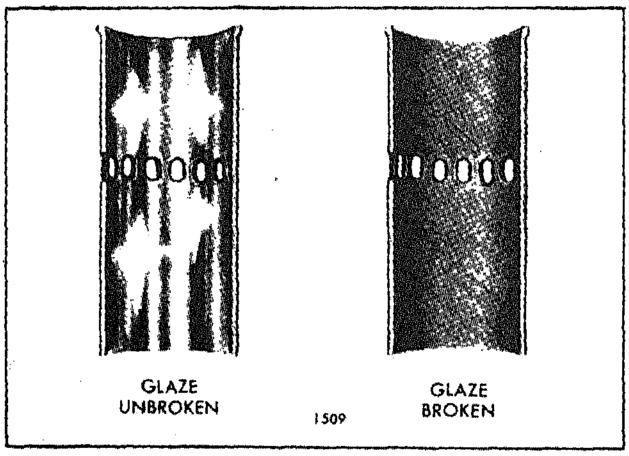


Fig. 5 · Glazed Surface of Cylinder Liner

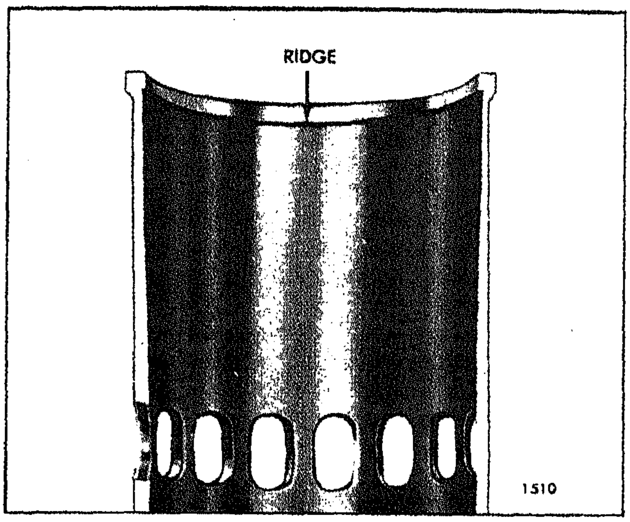


Fig. 6 - Cylinder Liner Ridge Due to Wear

Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone.

Install the liner in the proper bore of the cylinder block and measure the inside diameter at the various points shown in Fig. 3. Use cylinder bore gage J 5347 (Fig. 4), which has a dial indicator calibrated in .0001" increments, as it is rather difficult to obtain accurate measurements with a micrometer. Set the cylinder bore gage on zero in master ring gage J 8385. Also check the liner for taper and out-of-round.

NOTE: Dial bore gage master setting fixture J 23059 may be used in place of the master ring gage.

To reuse the liner, the taper must not exceed .002" and the out-of-round must not exceed .003". In addition, the ridge formed at the top of the ring travel must be removed. If the out-of-round exceeds .003", rotate the liner 90° in the block bore and recheck.

Hone Used Cylinder Liner

A used cylinder liner must be honed for the following reasons:

1. To break the glaze (Fig. 5) which results after long periods of operation.

2. To remove the ridge (Fig. 6) formed at the top by the piston ring travel.

When a liner has been in service for a long period, the bore becomes very smooth or glazed due to the rubbing action of the piston rings. Unless this glaze is removed, the time required to seat new piston rings will be lengthened.

The ridge formed at the top of the liner by the travel of the piston rings must also be removed. Otherwise, interference with the travel of the new compression rings may result in ring breakage.

Therefore, even though the taper and out-of-round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

Whenever a liner is honed, it should be placed in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

The hone J 5902-01, equipped with 120 grit stones J 5902-14, should be worked up and down, at a speed of 300-400 rpm, the full length of the liner a few times in a criss-cross pattern that produces hone marks on a 45° axis. This operation may be performed with emery cloth if a hone is not available.

After the liner has been honed, remove it from the fixture and clean it thoroughly. Then dry it with compressed air and check the entire surface for burrs.

After honing, the liner must conform to the same limits on taper and out-of-round as a new liner and the piston-to-liner clearance must be within the specified limits (Section 1.0).

Inspect New Cylinder Liner

Both the former and current liners can be intermixed in In-line engines.

Install the cylinder liner in the block and measure the inside diameter at the various points shown in Fig. 3. Use dial bore gage J 5347 and set the gage on zero with master ring J 8385.

NOTE: Dial bore gage master setting fixture J 23059 may be used in place of the master ring gage.

A new cylinder liner is 3.8752" to 3.8767" on the inside diameter and should be straight from top to bottom within .001" and round within .002" total indicator reading when the liner is in place in the

block. Refer to Section 1.0 for the specified piston-to-liner clearance.

NOTE: Do not modify the surface finish in a new service cylinder liner. Since the liner is properly finished at the factory, any change will adversely affect the seating of the piston rings.

Fitting Cylinder Liner in Block Bore

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean so the liner flange will seat properly. Then slide the liner into the block until the flange rests on the bottom of the counterbore in the block.

CAUTION: Do not drop or slam the liner flange against the bottom of the counterbore in the block.

2. Tap the liner lightly with a soft hammer to make certain the liner flange seats on the bottom of the counterbore.

3. Clamp the liner in place with hold-down clamp J 21793 and measure the distance from the top of the liner flange to the top of the block with dial indicator set J 22273 (Fig. 7). The top of the liner flange should be .0465" to .0500" below the top of the block, and there must not be over .0015" difference in depth between any two adjacent liners when measured along the cylinder longitudinal center line. If the above limits are not met, install the liner in another bore and recheck, or use a new liner.

4. Matchmark the liner and the cylinder block with chalk or paint so the liner may be reinstalled in the same position in the same block bore. Place the matchmark on the engine serial number side of the block (In-line engine).

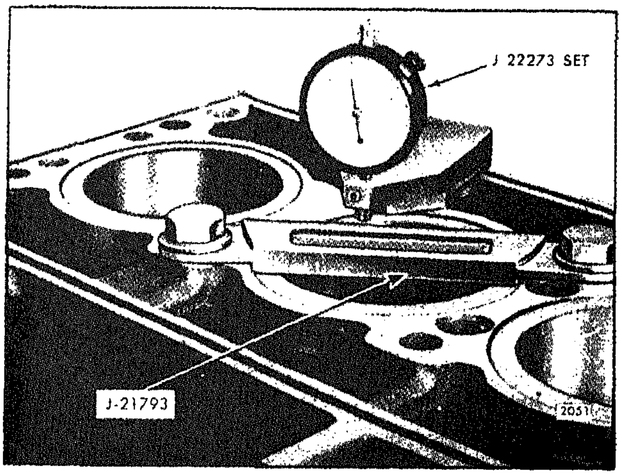


Fig. 7 - Checking Distance of Liner Flange Below Top Face of Block

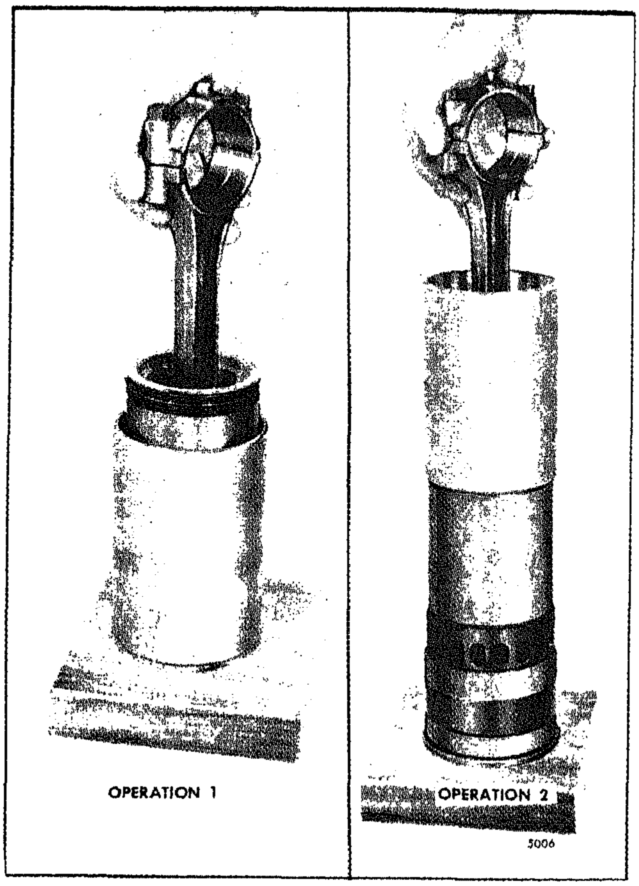


Fig. 8 - Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

5. Remove the hold-down clamp and the cylinder liner.

Install Piston and Connecting Rod Assembly

1. With the piston assembled to the connecting rod and the piston rings in place as outlined in Sections 1.6 and 1.6.1, apply Cindol 1705 oil to the piston, rings and the inside surface of the piston ring compressor J 6883.

NOTE: Inspect the ring compressor for nicks or burrs, especially at the non-tapered inside diameter end. Nicks or burrs on the inside diameter of the compressor will result in damage to the piston rings.

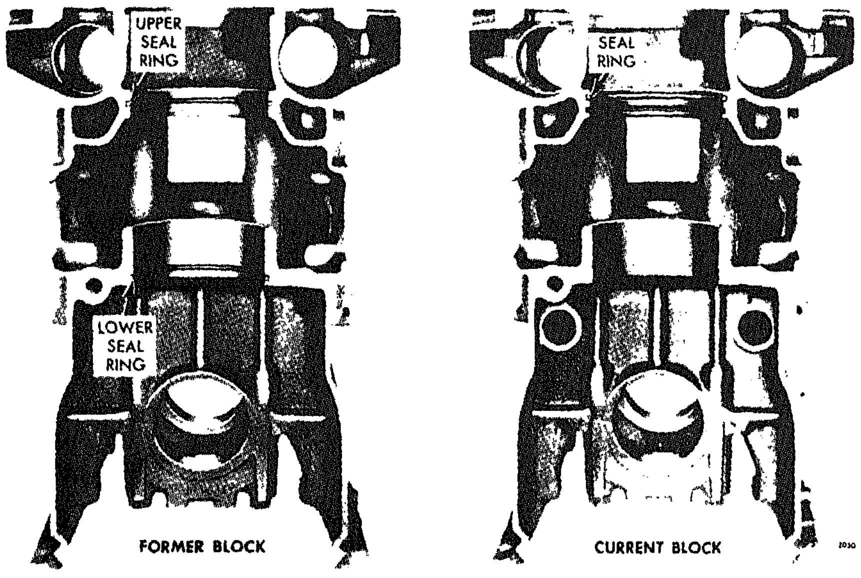


Fig. 9 - Cylinder Liner Seal Ring Location in Cylinder Block Bore

2. Place the piston ring compressor on a wood block, with the chamfered end of the ring compressor facing up.

3. Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

4. Start the top of the piston straight into the ring compressor. Then push the piston down until it contacts the wood block (Operation 1 of Fig. 8).

5. Note the position of the matchmark and place the liner, with the flange end down, on the wood block.

6. Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner (Operation 2 of Fig. 8).

> **NOTE:** The numbers, or number and letter, on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers, or number and letter, must be stamped in the same location as on the connecting rod that was replaced.

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.

> **CAUTION:** Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

8. Remove the connecting rod cap and the ring compressor. Then push the piston down until the compression rings pass the cylinder liner ports.

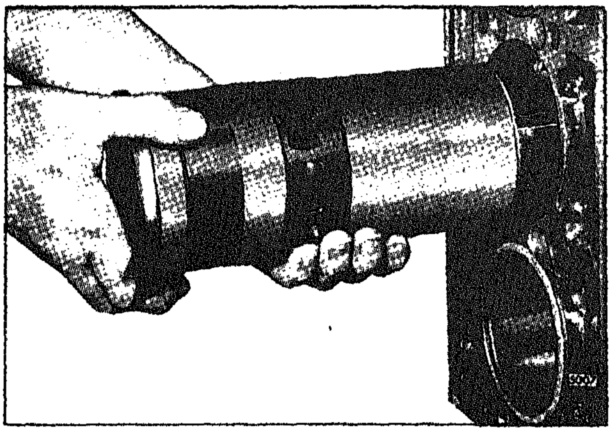


Fig. 10 - Installing Piston, Rod and Liner Assembly in Cylinder Block

Install Cylinder Liner, Piston and Connecting Rod Assembly

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine as follows:

1. Make sure the seal ring groove in the cylinder block is clean. Then install a new seal ring.

> **NOTE:** The current cylinder block has an additional seal ring groove approximately 1/8" below the original top groove (Fig. 9). This groove will permit further use of the cylinder block where corrosion or erosion of the upper seal ring groove has occurred. The lower seal ring groove in the current cylinder block has been eliminated. Reinstallation of the lower seal ring is not necessary in the former cylinder block.

2. Apply hydrogenated vegetable type shortening or permanent type antifreeze to the inner surface of the seal ring.

3. If any of the pistons and liners are already in the engine, use hold-down clamps (Fig. 7) to retain the liners in place when the crankshaft is rotated.

4. Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.

5. Install the upper bearing shell -- the one with a short oil groove at each parting line -- in the connecting rod. Lubricate the bearing shell with clean engine oil.

6. Position the piston, rod and liner assembly in line with the block bore (Fig. 10) so the identification number on the rod is facing the engine serial number side (In-line engine). Also align the matchmarks on the liner and the block. Then slide the entire assembly into the block bore and seal ring, being careful not to damage the seal ring.

7. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

8. Place the lower bearing shell -- the one with the continuous oil groove from one parting line to the other -- in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.

9. Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. On the 3/8"-24 bolts (In-line engines), tighten the nuts to 40-45 lb-ft torque.

10. Check the connecting rod side clearance. The clearance between the side of the rod and the crankshaft should be .006" to .012" with new parts on an In-line engine.

11. Install the remaining liner, piston and rod assemblies in the same manner. Use hold-down clamps to hold each liner in place.

12. After all of the liners and pistons have been installed, remove the hold-down clamps.

13. Install new compression gaskets and water and oil seals as outlined in Section 1.2. Then install the cylinder head and any other parts which were removed from the engine.

14. After the engine has been completely reassembled, refer to the *Lubricating Oil Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

15. Close all of the drains and fill the cooling system.

16. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the *run-in* schedule given in Section 13.2.1.

ENGINE BALANCE AND BALANCE WEIGHTS

In the balance of two-cycle engines, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds: unbalanced forces and unbalanced couples. These forces and couples are considered as primary or secondary according to whether their frequency is equal to engine speed or twice engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are of small consequence in comparison to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple due to their arrangement on the crankshaft.

On an In-line engine, it tends to rock the engine from end to end in a vertical plane. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the balance shaft and camshaft (In-line engine). This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

On the balance shaft and camshaft (In-line engine), each set of weights (weights on the outer ends of each shaft comprise a set) rotates in an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, cancelled. The front balance weights act in a direction opposite to the rear balance weights; therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple.

The balance weights are integral with the gears and the circular balance weights (pulleys) on the shafts. Additional weights are attached to the camshaft and balance shaft gears on three cylinder engines.

Both the rotating and primary reciprocating forces and couples are completely balanced in the engines. Consequently, the engines will operate smoothly and in balance throughout their entire speed range.

Remove Front Balance Weights

1. Remove the nut at each end of both shafts as outlined in Section 1.7.2.

2. Force the balance weight off the end of each shaft, using two screw drivers or pry bars between the balance weight and the upper front cover as shown in Fig. 1.

Install Front Balance Weights

1. Reinstall the Woodruff keys in the shafts, if they were removed.

2. Align the keyway in the balance weight with the key in the shaft, then slide the weight on the shaft. If the weight does not slide easily onto the shaft, loosen the thrust washer retaining bolts at the opposite end of the shaft. Then, to prevent possible damage to the thrust washer, support the rear end of the shaft while tapping the weight into place with a hammer and a

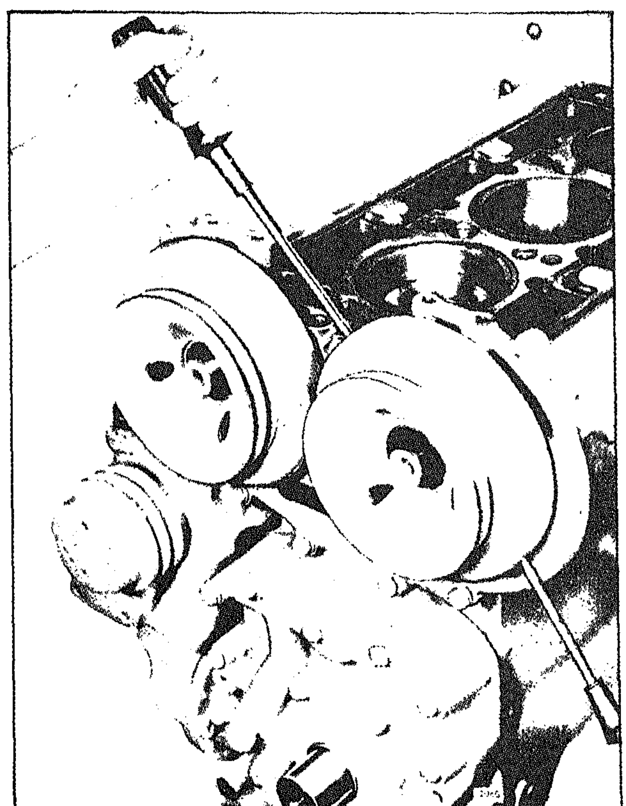


Fig. 1 - Removing Front Balance Weight (Pulley Type)

sleeve. Retighten the thrust washer retaining bolts to 30-35 lb-ft torque. Install the other weight in the same manner.

3. Wedge a clean rag between the gears. Refer to Fig. 1 of Section 1.7.2 and tighten the gear retaining nuts to 300-325 lb-ft torque. Then tighten the front balance weight retaining nuts to 300-325 lb-ft torque. Remove the rag from the gears.

GEAR TRAIN AND ENGINE TIMING

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the Series 53 engines.

The gear train on an In-line engine (Fig. 1) consists of a crankshaft gear, an idler gear, a camshaft gear, and a balance shaft gear. The governor drive gear, the upper blower rotor gear for the three cylinder engines,
are driven by the camshaft gear or balance shaft gear, depending upon the engine model.

On In-line engines, the crankshaft gear is pressed on and keyed to the end of the crankshaft.

The idler gear rotates on a stationary hub.

The camshaft and balance shaft gears on In-line engines
are pressed on and keyed to their respective shafts and each gear is secured by a retaining nut and lock plate.

The crankshaft, idler, camshaft and balance shaft gears on In-line engines are completely interchangeable with each other

On In-line engines, the camshaft and balance shaft gears have additional weights attached to the rear face of each gear.
These weights are important in maintaining perfect engine balance.

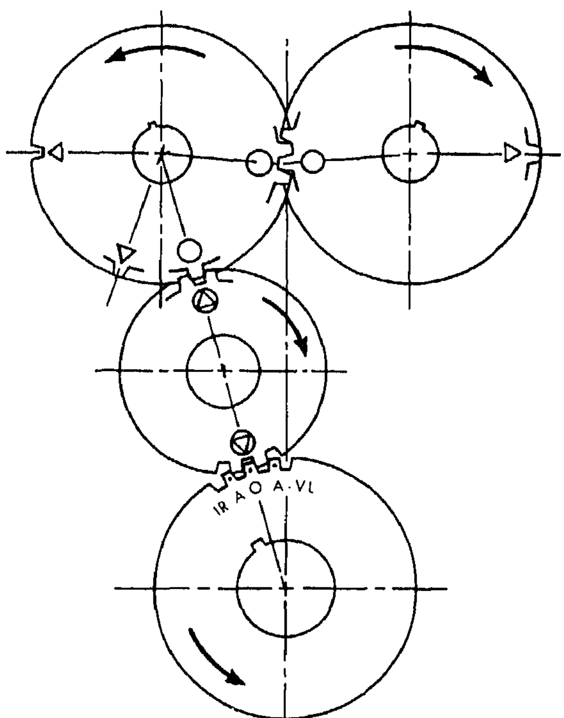


Fig. 1 - In-Line Engine Gear Train Timing Marks (Standard Timing Shown)

The camshaft and balance shaft gears on an In-line engine mesh with each other and run at the same speed as the crankshaft gear. Since the camshaft gears must be in time with each other, and the two as a unit in time with the crankshaft gear, timing marks have been stamped on the face of the gears to facilitate correct gear train timing.

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, it is important to remember the engine rotation. Then, working from the crankshaft gear to the idler gear and to the camshaft and/or balance shaft gear in that order, line up the appropriate circle symbols on the gears or the appropriate triangles as each gear assembly is installed on the engine. Refer to Fig . 1 for a typical gear train timing arrangement.

> **NOTE:** It is advisable to make a sketch indicating the position of the timing marks BEFORE removing or replacing any of the gears in the gear train.

The circle and the triangle are the basic timing symbols stamped on the gears. The letters stamped on the crankshaft gears identify the proper timing marks for the particular engine: "I" represents "In-line" engine, "R" represents right-hand rotation engine, and "A" represents advanced timing.

Effective with engine serial numbers 3D-64404, all Series 53 vehicle engines are built with advanced timing. The timing is advanced by aligning the proper "A" timing mark on the crankshaft gear with the circle-triangle timing mark on the idler gear.

IN-LINE ENGINE:

The camshaft and balance shaft gears are positioned so that the circle timing marks are adjacent to each other (Fig. 1). One circle-triangle timing mark on the idler gear is aligned with the second "circle" on the mating camshaft (or balance shaft) gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "IR-A" on the left

side of the circle timing mark (Fig. 1)for a right-hand rotation engine. For *standard timing*, the circle on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" adjacent to the "IR" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

Lubrication

The gear train is lubricated by the overflow of oil from the camshaft and balance shaft pockets spilling into the gear train compartment. A certain amount of the oil also spills into the gear train compartment from the camshaft and balance shaft end bearings and the idler gear bearing.

ENGINE TIMING

The correct relationship between the crankshaft and camshaft(s) must be maintained to properly control fuel injection and the opening and closing of the exhaust valves.

The crankshaft timing gear can be mounted in only one position since it is keyed to the crankshaft. The camshaft gear(s) can also be mounted in only one position due to the location of the keyway relative to the cams. Therefore, when the engine is properly timed, the markings on the various gears will match as shown in Fig . 1.

Pre-ignition, uneven running and a loss of power may result if an engine is "out of time".

When an engine is suspected of being out of time, due to an improperly assembled gear train, a quick check can be made without removing the flywheel and flywheel housing by following the procedure outlined below.

Check Engine Timing

Access to the crankshaft pulley, to mark the top dead center position of the selected piston, and to the front end of the crankshaft or the flywheel for turning the crankshaft is necessary when performing the timing check. Then, proceed as follows:

1. Clean and remove the valve rocker cover.

2. Select any cylinder for the timing check.

3. Remove the injector as outlined in Section 2.1 or 2.1.1.

4. Carefully slide a rod, approximately 12″ long, through the injector tube until the end of the rod rests on top of the piston. Place the throttle in the no-fuel position. Then, turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of [illegible]on, between 1/16 and 1/8 of a turn.

[illegible] .001″ graduations and a spindle movement of at least 1″. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also, select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.

6. Mount the indicator over the injector tube. Check to be sure the indicator spindle extension is free in the injector tube and is free to travel at least one inch.

7. Attach a suitable pointer to the engine lower front cover. The outer end of the pointer should extend out over the top of the crankshaft pulley.

8. Turn the crankshaft slowly, in the direction of engine rotation, until the indicator hand just stops moving.

9. Continue to turn the crankshaft, in the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is .010″.

Engine	*INDICATOR READING		
	Standard	Retarded 1-Tooth	Advanced 1-Tooth
	STANDARD TIMING		
(1) 3	.228"	.204"	.245"
(2) 3	.206"	.179"	.232"
	ADVANCED TIMING		
(2) 3	.232"	.206"	.258"

* Indicator readings shown are nominal values. The allowable tolerance is ± .005 in.
(1) High velocity type injector cam.
(2) Low velocity type injector cam.

TABLE 1

10. Scribe a line on the crankshaft pulley in line with the end of the pointer.

11. Slowly turn the crankshaft, opposite the direction of rotation, until the indicator hand stops moving.

12. Continue to turn the crankshaft, opposite the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is .010".

13. Scribe the second line on the crankshaft pulley in line with the end of the pointer.

14. Scribe a third line on the pulley half way between the first two lines. This is top dead center.

> **NOTE:** If the crankshaft pulley retaining bolt loosened up, tighten it to the torque specified in Section 1.0.

15. Remove the dial indicator and rod from the engine.

16. Install the injector as outlined in Section 2.1 or 2.1.1. Then, refer to Section 14 and adjust the exhaust valve clearance and time the fuel injector.

17. Turn the crankshaft, in the direction of rotation, until the exhaust valves in the cylinder selected are completely open. Reinstall the dial indicator so the indicator spindle rests on the top of the injector follower. Then, set the indicator on zero. Next turn the crankshaft slowly, in the direction of rotation, until the center mark on the pulley is in line with the pointer.

18. Check the front end of the camshaft for an identification mark. For identification purposes, a letter "V" is stamped on each end of a low velocity camshaft; but a letter "V" is not stamped on a high velocity camshaft. Note the indicator reading and compare it with the dimensions listed in Table 1 for the particular camshaft in the engine.

19. Remove the dial indicator; also remove the pointer attached to the front of the engine.

20. Install the valve rocker cover.

CAMSHAFT, BALANCE SHAFT AND BEARINGS

The camshaft and balance shaft used in the In-line engines, are located just below the top of the cylinder block. The camshaft and balance shaft in the In-line engines may be positioned on either side of the engine as required by the engine rotation and accessory arrangement.

The shafts are supported by bearings (bushing type) that are pressed into bores in the cylinder block. The balance shaft is supported by front and rear bearings only, whereas the camshaft is supported by end, intermediate and center bearings.

The camshafts in the three cylinder engine are supported by two end bearings and two intermediate bearings.

To facilitate assembly, letters signifying the engine models in which a shaft may be used are stamped on the ends of the shaft. The letters on the timing gear end of the camshaft must correspond with the engine model. For example, the letters RC are stamped on a camshaft used in an RC model engine. For additional identification, a camshaft with no designation on the ends or a "7" stamped on the ends is a high-velocity high-lift camshaft. A camshaft stamped with a "V" or "V7" is a low velocity high-lift camshaft.

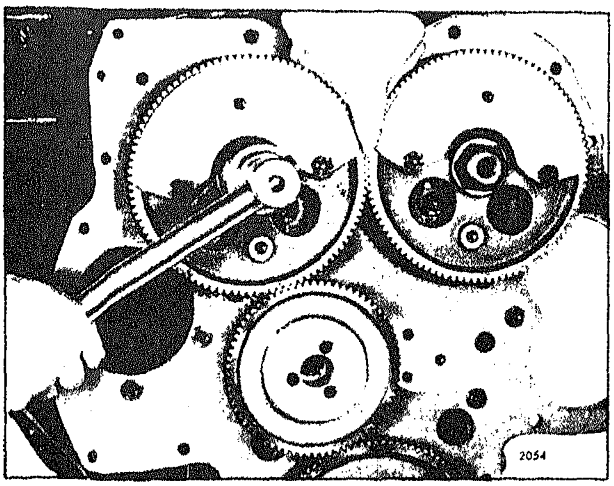


Fig. 1 - Removing or Installing Nut on Camshaft or Balance Shaft

NOTE: The low lift camshaft which provides a maximum valve cam lobe lift of .276 " is stamped "V7L" on both ends.

Lubrication is supplied under pressure to the camshaft and balance shaft end bearings via oil passages branching off from the main oil gallery direct to the camshaft end bearings.

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. On the current camshafts, the intermediate journal oil grooves were eliminated and a chamfer added to the intermediate journal oil holes. When replacing a former camshaft with a current camshaft, always use new bearings.

All of the camshaft and balance shaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

Remove Camshaft or Balance Shaft

Whenever an engine is being completely reconditioned or the bearings, thrust washers, or the gears need

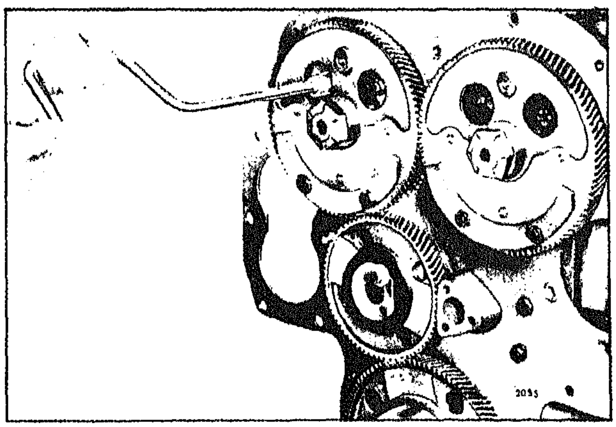


Fig. 2 - Removing or Installing Thrust Washer Retaining Bolts

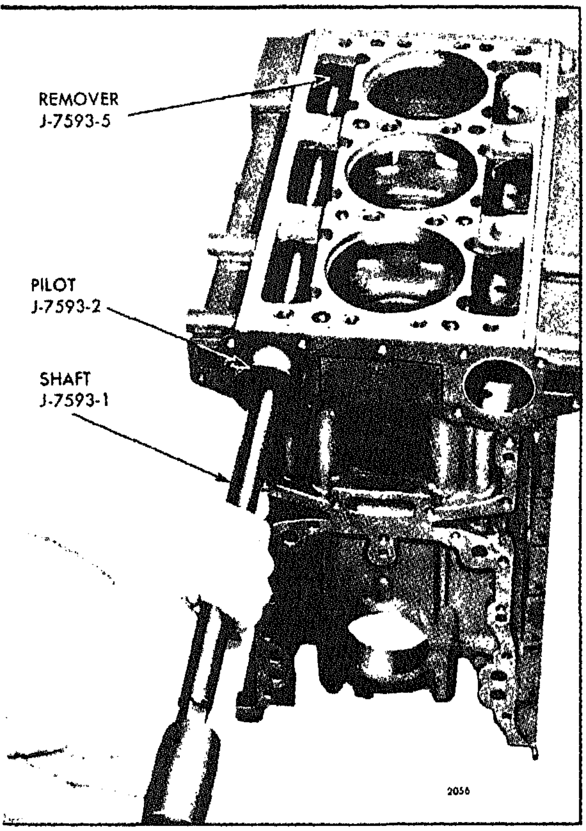


Fig. 3 · Removing End Bearing

placing, remove the shafts from the engine in the llowing manner:

NOTE: Refer to *Shop Notes* in Section 1.0 to install a cup plug in the front end of the camshaft.

Drain the engine cooling system.

Remove all accessories and assemblies with their taching parts as necessary to permit the engine to be ounted on an overhaul stand.

ocedures for removing accessories and assemblies om the engine will be found in their respective ctions of this manual.

Mount the engine on an overhaul stand. Be sure the gine is securely mounted on the stand before leasing the lifting sling.

Remove the cylinder head(s). Refer to Section 1.2.

Remove the flywheel and the flywheel housing as tlined in Sections 1.4 and 1.5.

Remove the bolts which secure the gear nut retainer plates (if used) to the gears, then remove the retainer plates.

7. Wedge a clean rag between the gears as shown in Fig. 1; then, remove the nuts from each end of both shafts with a socket wrench.

8. Remove the balance weights from the front end of the shafts as outlined in Section 1.7.

9. Remove the upper engine front cover (Section 1.7.8).

10. Remove the oil slinger from the front end of both shafts.

11. Remove the two retaining bolts that secure the camshaft or balance shaft thrust washer to the cylinder block by inserting a socket wrench through a hole in the web of the gear as shown in Fig. 2.

12. Withdraw the shaft, thrust washer and gear as an assembly from the rear end of the cylinder block.

Disassemble Camshaft or Balance Shaft

1. Remove the gear from the shaft. Refer to Section 1.7.3.

2. Remove the end plugs from the camshaft, to facilitate the removal of any foreign material lodged behind the plugs, as follows:

a. Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.

b. Make an indentation in the center of the camshaft end plug with a 31/64 " drill (carboloy tip).

c. Punch a hole as deeply as possible with a center punch to aid in breaking through the hardened surface of the plug.

d. Then, drill a hole straight through the center of the plug with a 1/4 " drill (carboloy tip).

e. Use the 1/4 " drilled hole as a guide and redrill the plug with a 5/16 " drill (carboloy tip).

f. Tap the drilled hole with a 3/8 "-16 tap.

g. Thread a 3/8 "-16 adaptor J 8183 into the plug. Then, attach a slide hammer J 6471-1 to the adaptor and remove the plug by striking the weight against the handle.

h. Insert a length of 3/8 " steel rod in the camshaft oil gallery and drive the remaining plug out.

NOTE: If a steel rod is not available, remove the remaining plug as outlined in Steps "a" through "g".

Inspection

Soak the camshaft in clean fuel oil. Then, run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the oil gallery and the oil holes with compressed air. Clean the camshaft bearings and related parts with fuel oil and dry them with compressed air.

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam rollers as outlined in Section 1.2.1.

Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces. Run out should not exceed .002 ".

CAMSHAFT AND BALANCE SHAFT CYLINDER BLOCK BORE MACHINING CHART

Engine	Bearing Location	Dimension Minimum	Dimension Maximum
3	End	2.385"	2.386"
3	Intermediate*	2.375"	2.376"

TABLE 1

Examine both faces of the thrust washers. If either face is scored or if the thrust washers are worn excessively, replace the washers. New thrust washers are .208 " to .210 " thick.

Also, examine the surfaces which the thrust washers contact; if these surfaces are scratched but not severely scored, smooth them down with an oil stone. If the score marks are too deep to be removed, or if parts are badly worn, use new parts.

The clearance between new shafts and new bearings is .0045 " to .006 ", or a maximum of .008 " with worn parts. Excessive clearance between the shafts and the bearings will cause low oil pressure and excessive backlash between the gears.

Bearings are available in .010 " and .020 " undersize for use with worn or reground shafts.

Oversize camshaft and balance shaft bearings are available in sets, .010 " oversize on the outside diameter, to permit reuse of a cylinder block having one or more scored block bearing bores. To use the oversize bearings, the camshaft and balance shaft block bores must be carefully line-bored (machined) to the dimensions shown in Table 1.

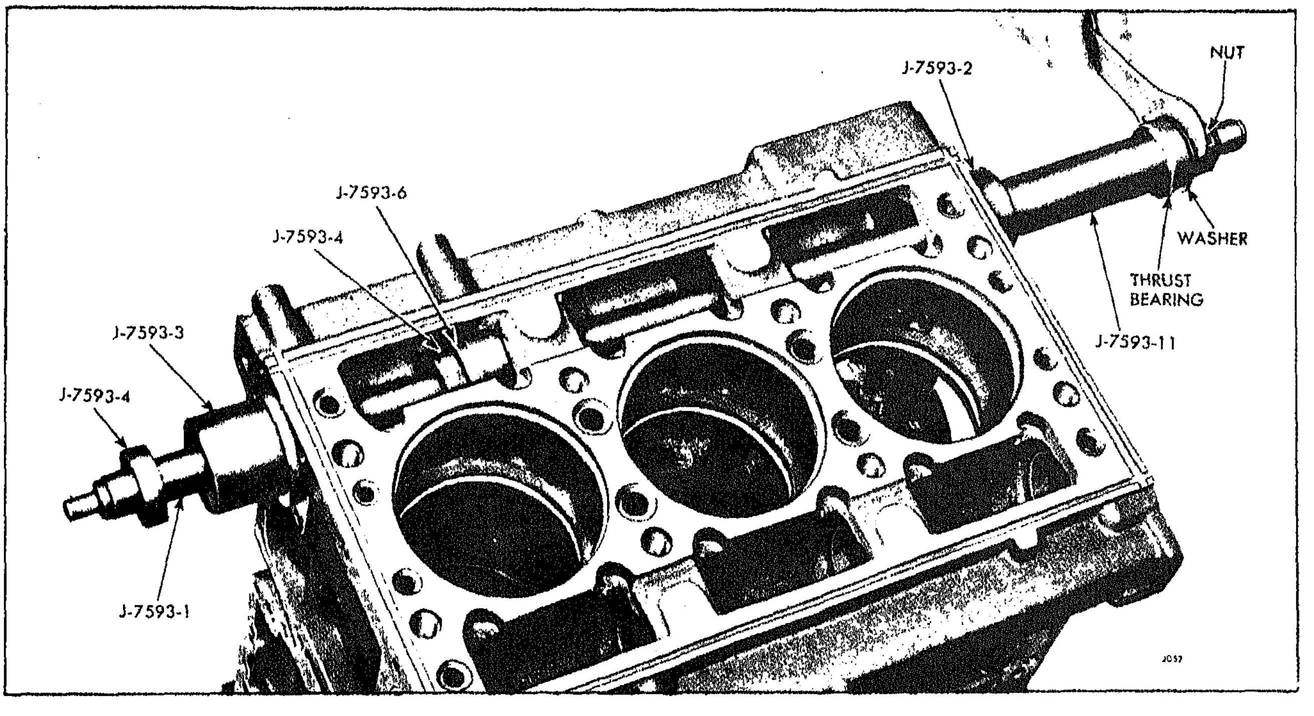


Fig. 4 - Installing Intermediate Camshaft Bearing

Remove Bearings

The end bearings must be removed prior to removing the intermediate bearings.

CAUTION: When removing the bearings be sure to note the position of the bearings in the bore with respect to the notch in the bearings. Replacement bearings must be installed in the same position.

1. Remove all accessories and assemblies with their attaching parts as is necessary so that tool set J 7593-02 may be used as shown in Fig. 3 and in A of Fig. 7.

Tool set J 7593-03, designed for use with standard size bearings, may be used to remove and install .010 " undersize and .020 " undersize bearings by reducing the pilot diameter of the pilot J 7593-2, installer J 7593-3, remover J 7593-5, installer J 7593-6, and installer J 7593-15. The pilot diameter of these tools should be reduced by .020 ". This reduction in tool diameter does not materially effect usage on standard size bearings. If the tools are used frequently, however, it may be advisable to purchase additional standard pieces. Reduced diameter tools have not been released.

2. Insert the small diameter end of the pilot J 7593-2 into the end bearing.

3. Then, with the unthreaded end of the shaft J 7593-1 started through the pilot, push the shaft through the block bore until the end of the shaft snaps into the remover J 7593-5.

4. Now drive the end bearing out of the cylinder block. The nearest intermediate and/or center bearings can be removed now in the same manner. The large diameter end of pilot J 7593-2 will fit into

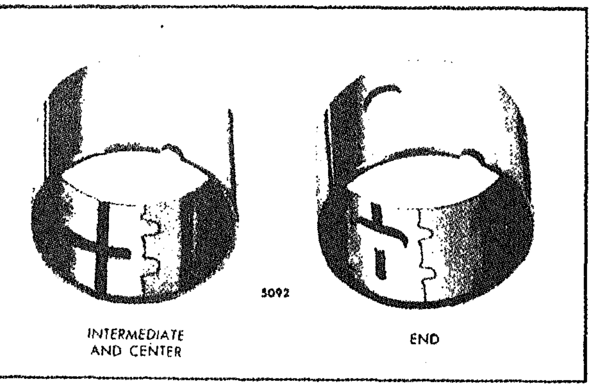


Fig. 5 - Camshaft and Balance Shaft Bearing Identification

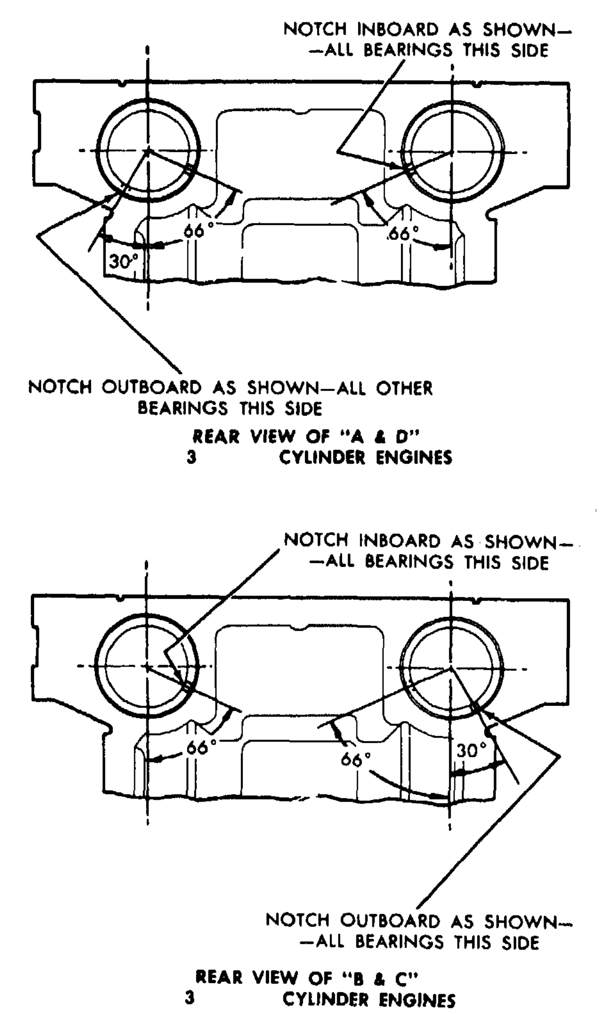


Fig. 6 - Location of Notch in Relation to Shaft Bore Centerline

the camshaft bore and is used when removing the other end bearing and any remaining bearings.

Install Intermediate and/or Center Camshaft Bearings

Camshaft center and intermediate bearings must be installed prior to installing the camshaft end bearings. On the four cylinder In-Line and 8V engine, the center, rear intermediate and rear bearings are installed in that order by pressing the bearings from the rear to the front of the block. The front intermediate and front bearings are installed by pressing the bearings from the front to the rear of the block. Bearings are similarly installed in the three cylinder and 6V engine except that there is no center bearing. The center bearing for the two cylinder block is installed by pressing the bearing from the rear to the front of the block.

NOTE: Current bearings incorporate lubrication grooves on the inner bearing surface (Fig. 5).

To properly install the camshaft and balance shaft bearings, refer to Fig. 6 for location of the notch in the bearing in relation to the camshaft or balance shaft bore centerline in the cylinder block.

Also, to facilitate assembly, the camshaft and balance shaft bearings are color coded on the side and/or end as shown in Table 2.

1. Insert pilot J 7593-2 in the bore of the block as shown in Fig. 4. Use the small end of the pilot if an end bearing has been installed. Refer to B and C of Fig. 7.

2. Insert the new intermediate or center bearing into the camshaft bore and position it correctly. Install the center bearing first.

3. Then, with the unthreaded end of shaft J 7593-1 started through the pilot, push the shaft through the entire length of the block bore.

4. Slide installer J 7593-6 on the shaft until the locating pin registers with the notch in the bearing. Then, slide installer J 7593-3 or J 7593-15 on the shaft with the large diameter inserted into the end of the block bore. Refer to C and note of Fig. 7.

5. Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the puller. The short spacer J 7593-11, shown in Fig. 4, is used on the three cylinder (In-Line) and 6V blocks. The long spacer J 7593-10 is used on the two cylinder block.

6. Align the shaft in such a way that a "C" washer, J 7593-4, can be inserted in a groove in the shaft adjacent to installer J 7593-6.

7. Place a "C" washer in the groove near the end of the shaft and, using a suitable wrench on the hex nut, draw the bearing into place until the "C" washer butts up against installer J 7593-3 and prevents the shaft from further movement.

CAMSHAFT AND BALANCE SHAFT
BEARING COLOR CODE CHART

Bearing Position	Color Code		Outside Diameter	Inside Diameter
	Current	Former		
End	Brown	Black	Standard	Standard, .010" & .020" U.S.
	Brown	Yellow	.010" Oversize	Standard (only)
Inter-mediate	Orange	Red	Standard	Standard, .010" & .020" U.S.
	Orange	Blue	.010" Oversize	Standard (only)

Table 2

Install End Bearings

Refer to the camshaft and balance shaft color code chart and the cylinder block bore machining dimension chart when installing the end bearings.

1. Insert pilot J 7593-2 in the bore of the block as shown in "D" of Fig. 7. Use the small diameter of the pilot if a bearing has been installed.

2. Insert support J 7593-12 in the bore in the opposite end of the block; then, with the unthreaded end of the shaft started through pilot J 7593-2, push the shaft through the block and support J 7593-12.

3. Place a new end bearing on installer J 7593-3 and align the notch in the bearings with the pin on the installer. Then, slide the installer and the bearing on the shaft. Position the bearing correctly with the groove in the camshaft bore.

4. Place "C" washer J 7593-4 in the end notch in the shaft; pull the shaft back until the washer butts against the installer.

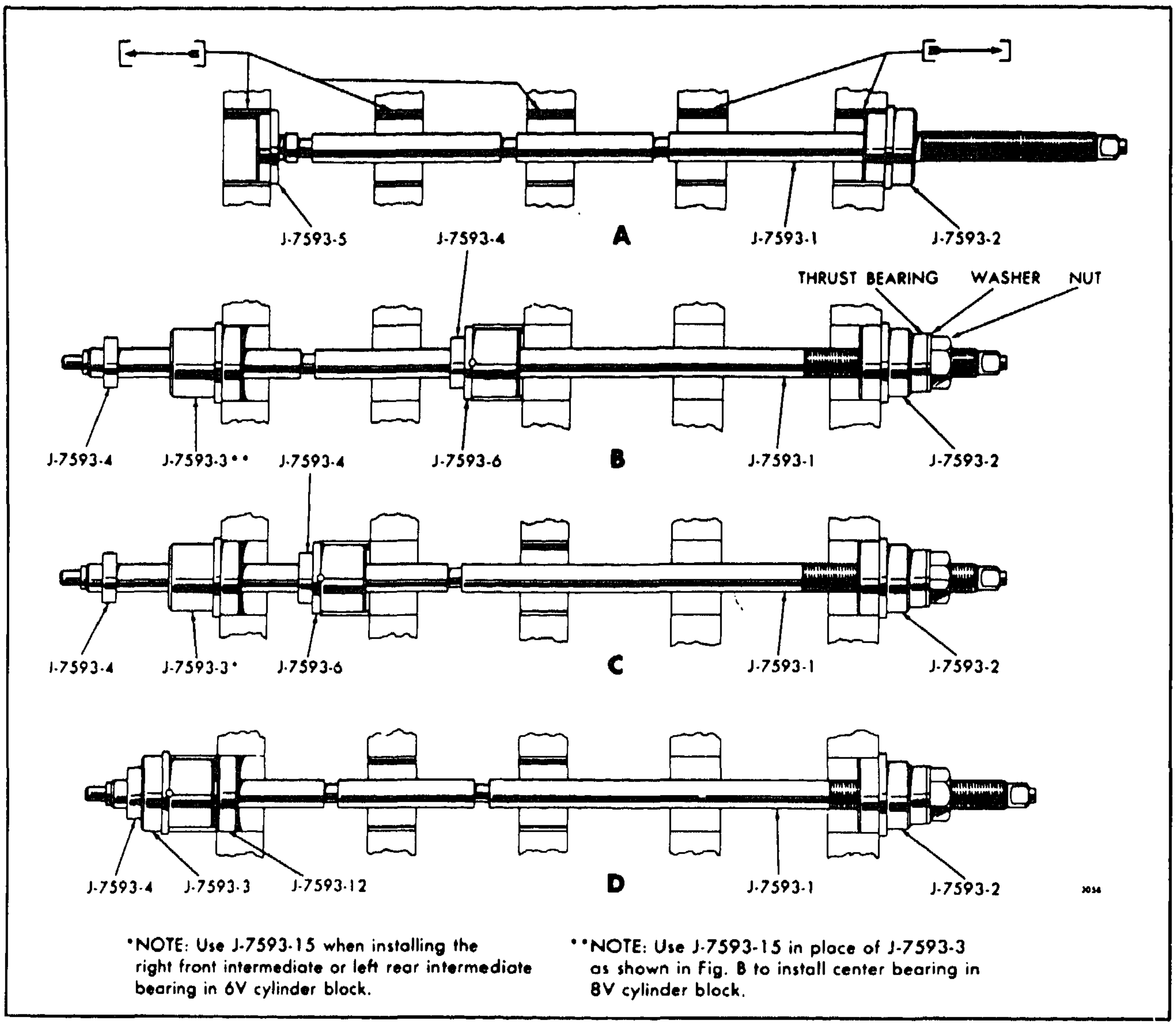


Fig. 7 · Removing and Replacing Camshaft or Balance Shaft Bearings

5. Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the shaft as shown in "D" of Fig. 7 and, using a suitable wrench on the hex nut, draw the bearing into place until the shoulder on the installer prevents the shaft from further movement. The bearing is now installed in its correct position.

Install the remaining end bearings in the same manner.

Use of tool J 7593-03 assures that the bearings are properly spaced in relation to the end of the block. The center bearing (notch end) for a four and 8V cylinder block is 10.94 " from the rear face of the block. The center bearing for the two cylinder block is 5.54 " from the rear face of the block. The intermediate bearings for the four cylinder and three cylinder block are 5.54 " from the rear and front face of the block. The right rear and left front intermediate bearings for the 6V and 8V cylinder block are 5.54 " from the rear and front face of the block; and the right front and left rear intermediate bearings are 6.66 " from the front and rear face of the block.

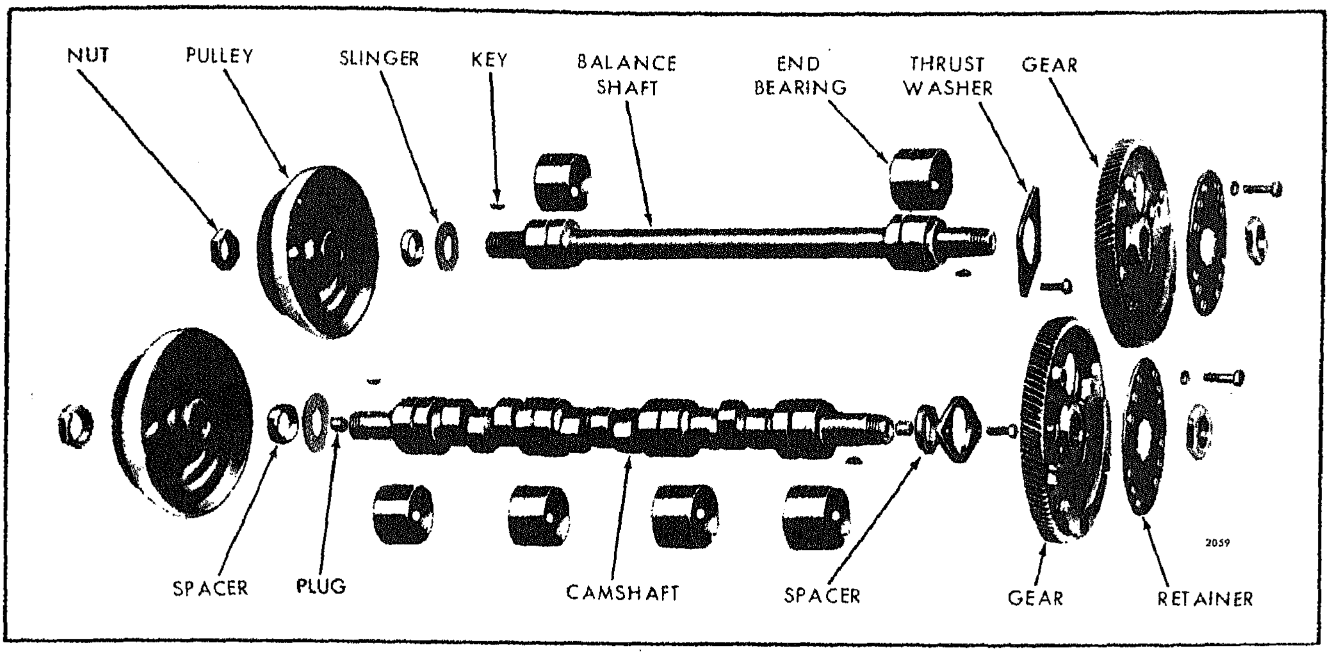


Fig. 8 - Camshaft and Balance Shaft Details and Relative Location of Parts

Assemble and Install Camshaft and Balance Shaft

Refer to Fig. 8 and assemble the camshaft and balance shaft.

1. Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940 " to 2.060 ".

2. Install the gears and thrust washers on their respective shafts as outlined in Section 1.7.3.

3. Lubricate the bearings and shafts with engine oil and slide the shaft assemblies into the cylinder block being careful not to damage the bearings or the cams and journals. Make sure that the appropriate timing marks on the gears are aligned. Refer to *Gear Train and Engine Timing* in Section 1.7.1.

4. Slide an oil slinger on the front end of both shafts.

5. Install the upper engine front cover, if used, (Section 1.7.8).

6. Secure the thrust washers in place as shown in Fig. 2 and tighten the bolts to 30-35 lb-ft torque.

7. Install the front balance weights (Section 1.7).

8. Attach the gear nut retainer plates (if used) to the gears with bolts and lock washers and tighten the bolts to 35-39 lb-ft torque.

9. Check the clearance between the thrust washer and the gear on both shafts. The clearance should be .005 " to .015 ", or a maximum of .019 " with used parts.

10. Check the backlash between the mating gears. The backlash should be .003 " to .005 " and should not exceed .007 " between used gears.

11. Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective sections of this manual.

CAMSHAFT AND BALANCE SHAFT GEARS

The camshaft and balance shaft gears on an In-line engine are located at the flywheel end of the engine and mesh with each other and run at the same speed as the crankshaft.

Since the camshaft and balance shaft gears on In-line engines must be in time with each other, timing marks are stamped on the rim of each gear. Also, since these two gears as a unit must be in time with the crankshaft, timing marks are located on the idler and crankshaft gears (refer to Section 1.7.1).

Each gear is keyed to its respective shaft and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double hexagon hole in the center, fits over the nut on some engines. The retainer is attached to the gear by bolts threaded into tapped holes in the gear.

On the three cylinder In-line engines, external weights are attached to the rear face of each gear. The weights are important in maintaining perfect engine balance.

When new service gears are used on an In-line engine, the external weights on the old gears must be transferred to the new gears. If the weights are transferred to new gears, tighten the bolts to 45-50 lb-ft torque.

Remove Camshaft and Balance Shaft Gears

1. Remove the camshaft and the balance shaft from the engine as outlined in Section 1.7.2.

2. Place the camshaft and gear assembly in an arbor press with the gear suitably supported as shown in Fig. 1.

3. Place a wood block under the lower end of the camshaft so the threads will not be damaged when the shaft is pressed from the gear.

4. Place a short piece of 3/4" O.D. brass rod between the end of the camshaft and the ram of the press; then force the camshaft out of the camshaft gear.

5. Remove the thrust washer, Woodruff key and spacer from the camshaft.

6. Remove the gear from the balance shaft in a similar manner.

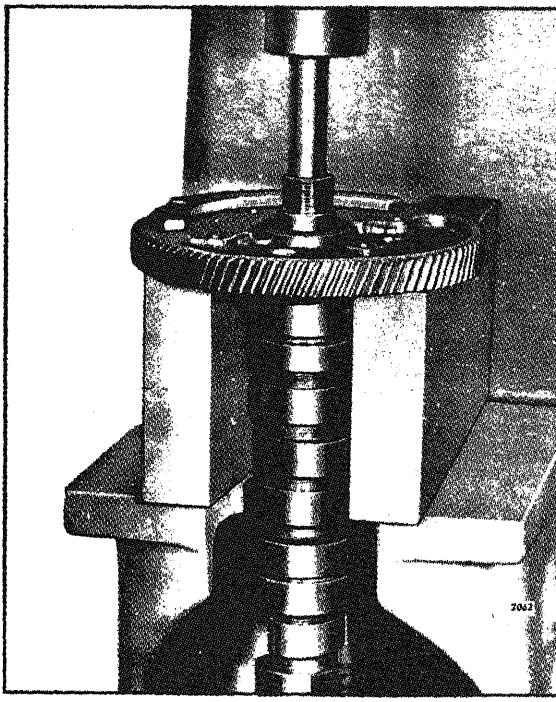


Fig. 1 - Removing Camshaft Gear

Inspection

Clean the gears with fuel oil and dry them compressed air. Then examine the gear teet evidence of scoring, pitting and wear. Replac gears if necessary.

Examine both faces of the camshaft and balance thrust washer and, if either face is worn or sc replace the washer. Also examine the surface o camshaft and balance shaft which the thrust w contacts. If this surface is scratched, but not sev scored, smooth it up with a fine oil stone.

Install Camshaft and Balance Shaft Gears

1. Note the letters stamped on the end of the cam which signify the engine models in which a cam may be used. The letters on the timing gear end camshaft must correspond with the engine moc the particular engine being assembled. Refer t front of this manual for engine model identificati

2. Place the rear camshaft spacer over the timing end of the camshaft and install the Woodruff key

3. Lubricate the thrust washer with clean engi and place the thrust washer over the gear end camshaft and the spacer.

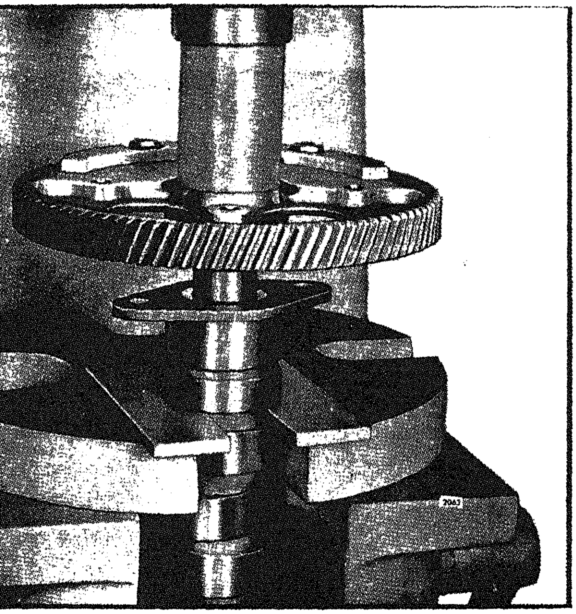


Fig. 2 - Installing Camshaft Gear

Start the camshaft gear over the end of the nshaft with the key in the shaft registering with the keyway in the gear.

5. Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and under the ram of the press. Bring the ram of the press down on the sleeve and press the gear tight against the spacer on the shaft (Fig. 2).

6. Measure the clearance between the camshaft thrust washer and the camshaft. This clearance should be .008" to .015" when new parts are used. With used parts, a maximum clearance of .021" is allowable.

7. Install the gear retaining nut on the camshaft by hand. Tighten the nut after the shaft is installed in the cylinder block.

8. Install the gear on the balance shaft in a similar manner. No rear spacer is used with the balance shaft gear, since the gear seats against a shoulder on the shaft.

9. Install the camshaft and balance shaft in the engine as outlined in Section 1.7.

IDLER GEAR AND BEARING ASSEMBLY

IN-LINE ENGINES

The engine idler gear and bearing assembly, located at the flywheel end of the engine, meshes with the camshaft and crankshaft gears and rotates on a stationary hub. The hub is secured directly to the cylinder block by a bolt which passes through the hub and three bolts which pass through the flywheel housing, hub and end plate (Fig. 1).

Two timing marks (a triangle within a circle) are stamped on the idler gear diametrically opposite (180 °) to one another.

The inside diameter of the idler gear bearing is 2.186 ″-2.187 ″ and the outside diameter of the idler gear hub is 2.1825 ″-2.1835 ″. Therefore, the clearance between the idler gear hub and the idler gear bearing is .0025 ″ to .0045 ″, with a maximum allowable wear limit of .007 ″.

A thrust washer is provided on both sides of the idler gear and bearing assembly. The standard thickness of the idler gear and bearing assembly is 1.233 ″ to 1.234 ″ and the standard thickness of the two thrust washers is .236 ″ to .240 ″; thus, the clearance between the thrust washers and the idler gear is .006 ″ to .013 ″, with a maximum allowable wear limit of .017 ″.

On an In-line engine, the idler gear is positioned on the left-hand side for a right-hand rotating engine

as viewed from the rear. Refer to Fig. 5 under *General Description.*

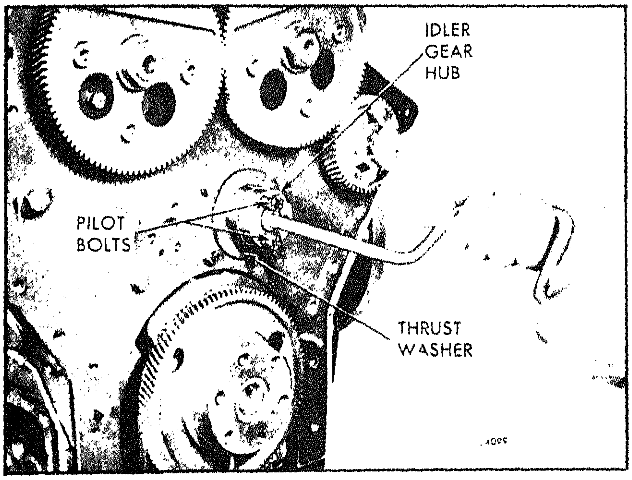


Fig. 1 - Installing Idler Gear Hub

On early engines, an idler gear spacer (dumm
was used on the side opposite the idler gear. Cu
the flywheel housing has an integral cast hub
.015 ″ thick shim is used between the flywheel h
and the end plate.

Remove Idler Gear and Bearing Assembly (Flywheel Housing Removed)

1. Remove the idler gear outer thrust washer fr
idler gear hub (Fig. 3).

2. Slide the idler gear straight back off of th
gear hub.

3. Remove the bolt which secures the idler gear

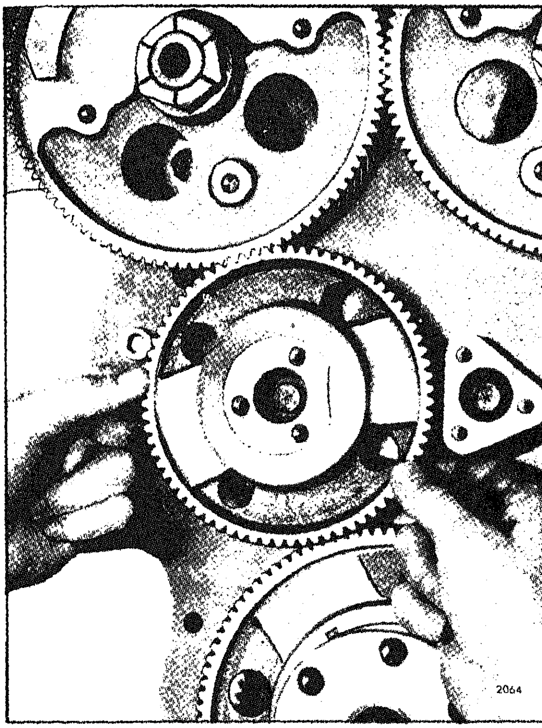


Fig. 2 - Installing Idler Gear

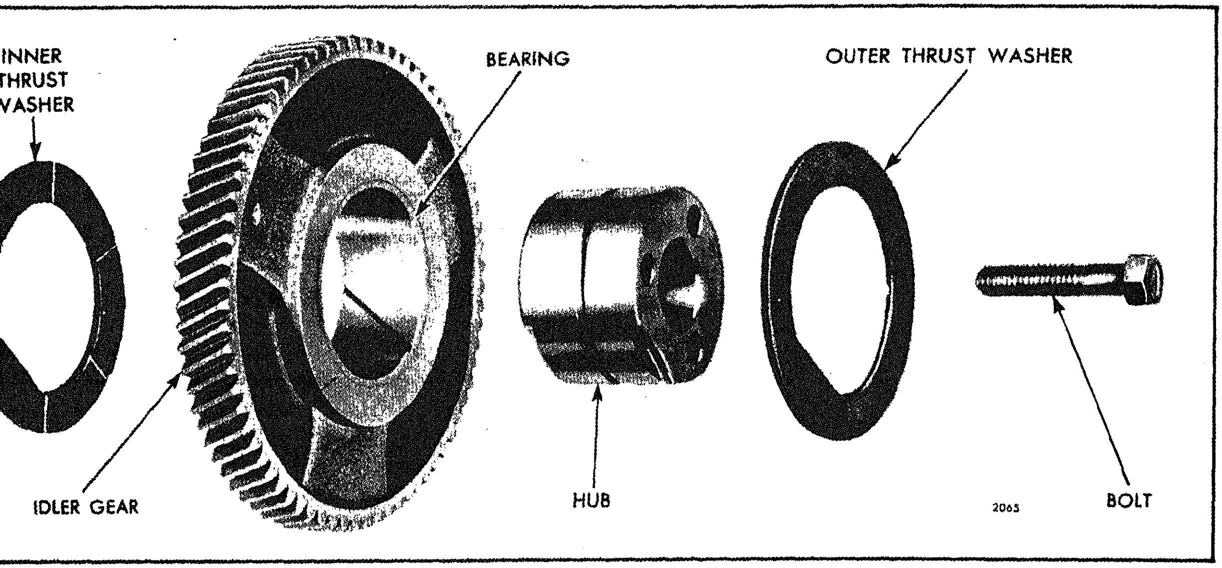


Fig. 3 - Idler Gear Details and Relative Location of Parts

linder block. Then remove the idler gear hub
e idler gear inner thrust washer as an assembly.

tion

the idler gear and bearing assembly, hub and washers thoroughly in clean fuel oil and dry vith compressed air. Examine the gear teeth and g for scoring, pitting and wear. If the gear teeth orn or the bearing is scored, pitted or worn vely, replace the gear and bearing assembly or a new bearing in the gear. Examine the outside er of the idler gear hub and thrust washers; if or worn excessively, replace them.

er gear bearing with two oil grooves has been orated in the idler gear and bearing assemblies ing with engine serial number 3D-

a new bearing is installed in the idler gear, it ot protrude beyond the gear face on either side.

Idler Gear and Bearing Assembly

e the inner thrust washer on the forward end of er gear hub with the flat in the inner diameter thrust washer over the flat on the end of the ıb and with the oil grooyes in the thrust washer the idler gear.

e the small protruding end of the idler gear hub through the end plate and into the counterbore in the cylinder block.

3. Insert two 3/8 ″-16 bolts through the idler gear hub and thread them into the cylinder block, as shown in Fig. 1, to be sure the bolt holes will be in alignment when the flywheel housing is installed.

4. Insert the 3/8 ″-16x1-3/4 ″ special bolt through the center of the idler gear hub and thread it into the cylinder block. Tighten the bolt to 40-45 lb-ft torque. Then remove the two 3/8 ″-16 bolts previously installed for alignment of the gear hub.

5. Lubricate the idler gear hub and idler gear bearings liberally with clean engine oil.

6. Position the crankshaft gear and the camshaft gear or balance shaft gear so that their timing marks will align with those on the idler gear. Refer to Figs. 1 and 2 in Section 1.7.1.

7. With these timing marks in alignment, install the idler gear as shown in Fig. 2.

8. Apply a thin film of cup grease to the inner face (face with the oil grooves) of the outer idler gear thrust washer. Then place the thrust washer over the end of the idler gear hub with the oil grooves in the side of the thrust washer facing the idler gear and the flat in the inner diameter of the thrust washer over the flat on the end of the idler gear hub.

9. Check the backlash between the mating gears. The backlash should be .003 ″ to .005 ″ between new gears and should not exceed .007 ″ between used gears.

CRANKSHAFT TIMING GEAR

In-line Engine

The crankshaft timing gear is keyed and pressed on the crankshaft and drives the camshaft gear (In-line engines) or balance shaft gear (In-line engines) through an idler gear.

Since the camshaft must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (refer to Section 1.7.1).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft timing gear is a .001 " to .003 " press fit on the crankshaft. Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.

2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.

3. Attach bar type puller J 4871 to the crankshaft gear with three long bolts or hooks, flat washers and nuts through the holes in the gear as shown in Fig. 1.

4. Turn the center screw of the puller to pull the crankshaft gear off of the crankshaft.

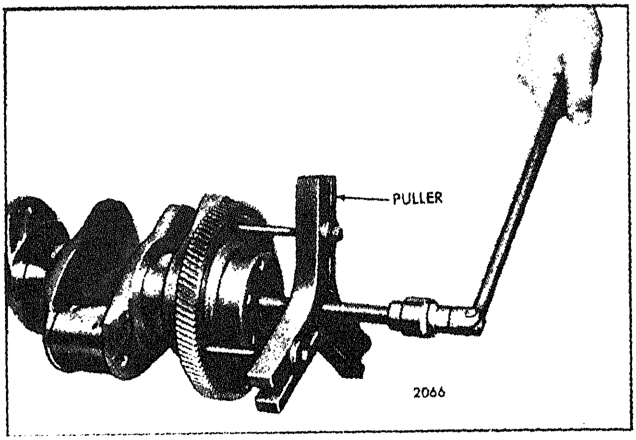


Fig. 1 - Removing Crankshaft Timing Gear

Inspection

Clean the gear with fuel oil and dry it compressed air. Examine the gear teeth for evi of scoring, pitting or wear. If severely damag worn, install a new gear. Also check the other ge the gear train.

Install Crankshaft Timing Gear

1. If removed, install the Woodruff key in the ke in the crankshaft.

2. Start the timing gear over the end of the crank with the timing marks on the outer rim of the facing out and the keyway in the gear in align with the Woodruff key in the crankshaft.

3. Align the proper timing mark on the crank gear with the corresponding mark on the idler (refer to Section 1.7.1).

> **NOTE:** When advanced timing is required, ali the timing mark "A" with the timing mark the idler gear.

4. Place a heavy hammer against the head of th in the front end of the crankshaft. Place ins J 7557 against the rear face of the timing gea

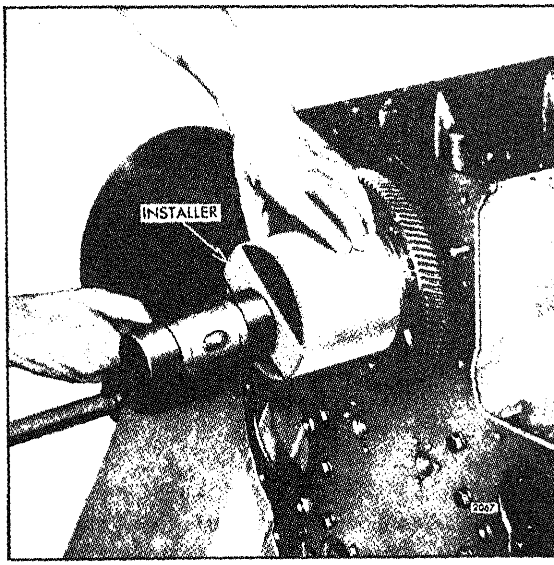


Fig. 2 - Installing Crankshaft Timing Gear

the gear up against the shoulder on the aft as shown in Fig. 2.

k the gear backlash with the mating gear. The backlash should be .003 ″-.005 ″ with new gears or .008 ″ maximum with used gears.

6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

ACCESSORY DRIVE

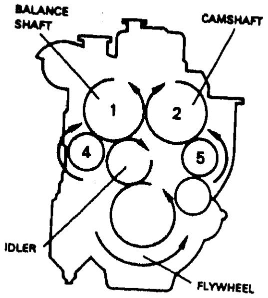


Fig. 1 - Accessory Drive Locations (In-Line Engines)

Accessory drives have been provided at the rear of the engines to accommodate both gear driven and belt driven accessories.

For the accessory drive locations and rotation

of the drive at a particular position, refer to Fig

The drive for direct gear driven accessories, such as compressors or hydraulic pumps, consists of a d

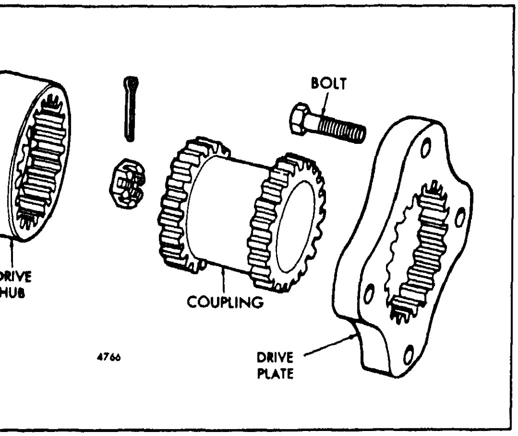


Fig. 3 - Air Compressor Drive

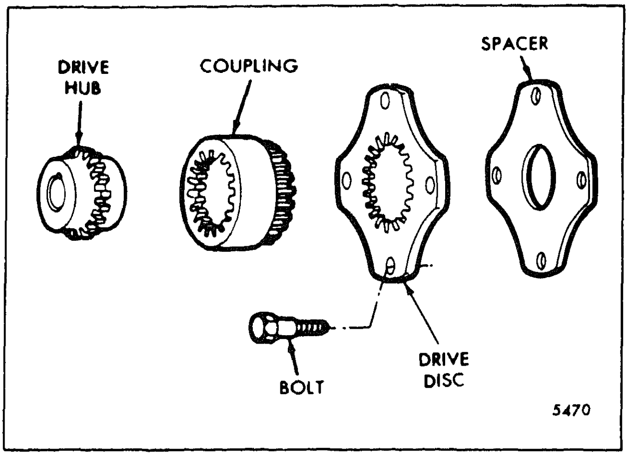


Fig. 4 - Hydraulic Pump Drive

pling and drive plate (Fig. 3) or a spacer, te, drive coupling and hub (Fig. 4).

e plate and spacer, when used, are bolted to haft or balance shaft gear. The accessory is the flywheel housing and driven by a drive ed to the accessory shaft and splined to the which is splined to the drive plate attached to haft or balance shaft gear. The current drive shown in Fig. 4, has 21 external teeth; the oupling had 23 external teeth.

ven accessories, such as battery-charging s or air compressors, are driven off the or balance shaft gears by a drive hub and ig. 5), or a spacer, accessory drive plate, drive shaft, accessory drive retainer and pulley (Fig. 6).

t arrangement, illustrated in Fig. 5, the drive lted to the camshaft or balance shaft gear. eal retainer is bolted to the flywheel housing ulley is keyed to the drive hub shaft which rough the oil seal retainer.

econd arrangement, shown in Fig. 6, the d accessory drive plate are bolted to the or balance shaft gear. The accessory drive plined to the drive plate at one end and by a bearing in the accessory drive retainer

Remove Accessory Drive

Remove the direct gear driven type accessory drive as follows:

1. Remove any external piping or connections to the accessory.

2. Remove the five bolts and lock washers attaching the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing.

3. Remove the drive coupling.

4. Remove the drive hub from the accessory shaft, if necessary.

5. Place a clean, lintless cloth in the flywheel housing opening, underneath the accessory drive plate, to prevent bolts from accidentally falling into the gear train. Remove the lock wires, if used. Then remove the four bolts (and lock washers, if used) and remove the accessory, the drive plate and the spacer, if used.

Remove the drive assembly for a belt driven type accessory as follows:

1. Remove any external piping or connections to the accessory.

2. Loosen the accessory and slide it toward the drive pulley. Then remove the drive belt and accessory.

3. Remove the bolt and washer (Fig. 5), or nut (Fig. 6), retaining the pulley on the drive shaft.

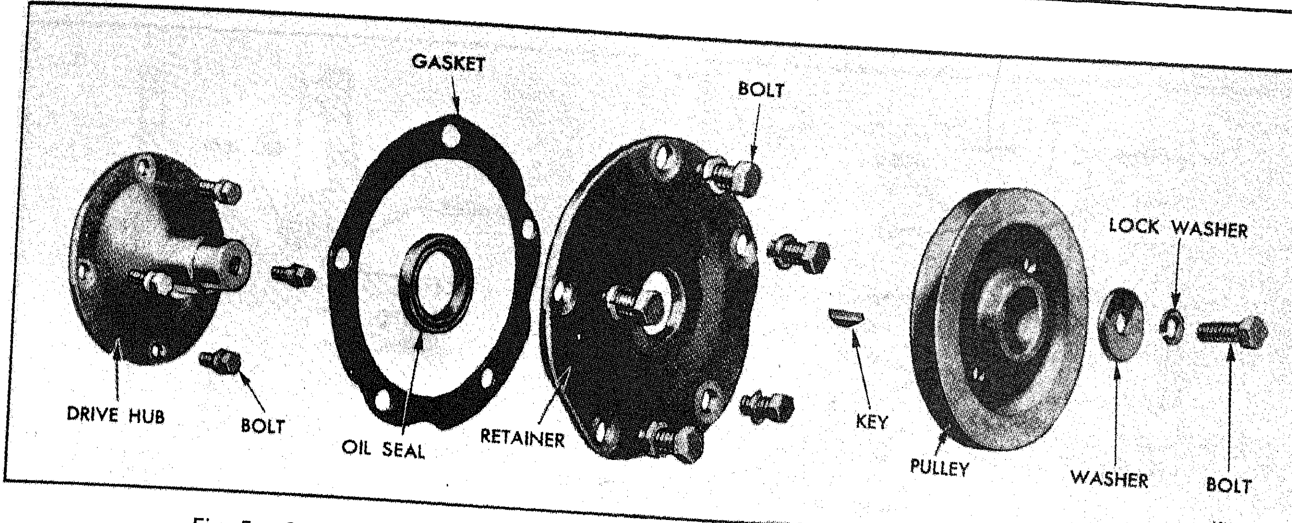


Fig. 5 - Components of Accessory Drive for Belt Driven Accessory (Drive Hub Type)

the drive retainer assembly to the flywheel housing. Remove the retainer assembly.

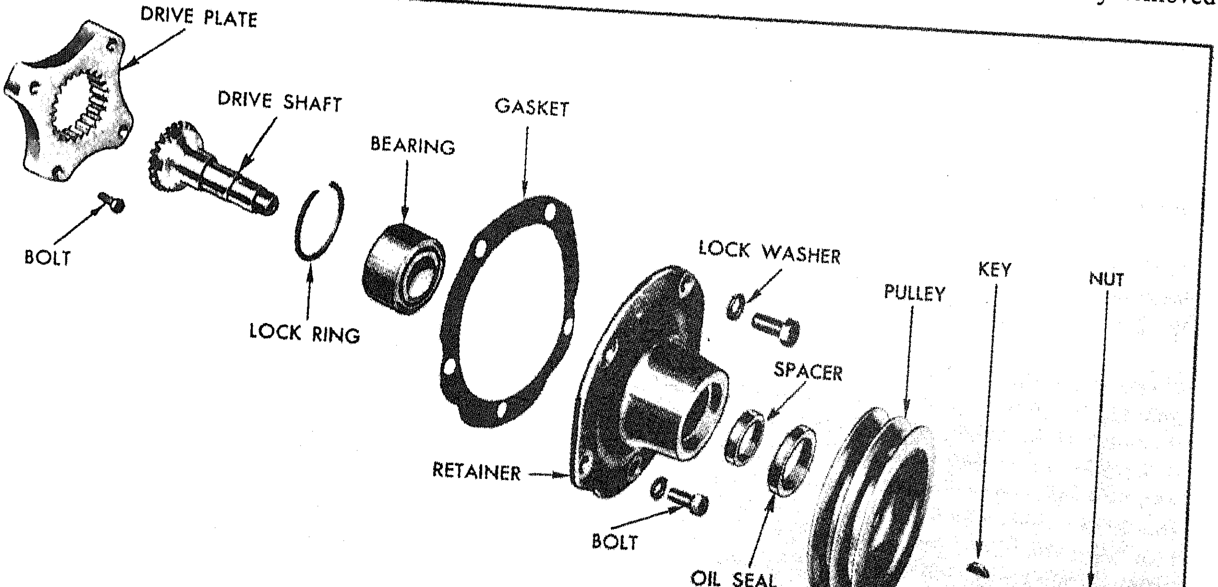
6. Remove the accessory drive shaft, drive plate and spacer (Fig. 6), or drive hub (Fig. 5), in a manner similar to that outlined in Step 5 under removal of the direct gear driven type accessory drive.

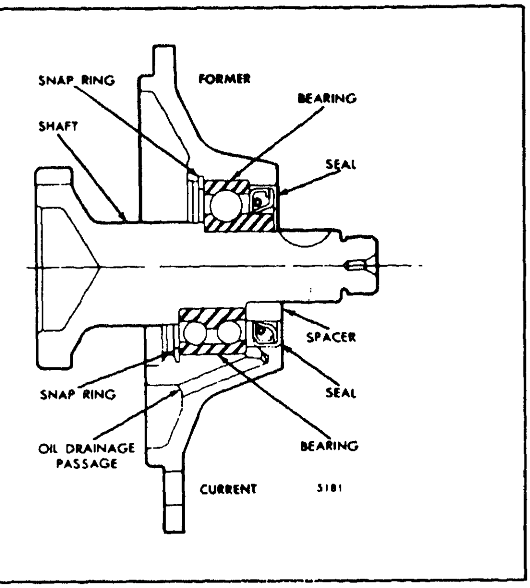
7. Remove the snap ring and ball bearing from the accessory drive shaft retainer assembly shown in Fig. 6.

Inspection

Clean the accessory drive parts with clean fuel oil and dry them with compressed air. Examine the gear teeth of the drive shaft, drive coupling, drive hub or drive plate for wear. If worn excessively, replace them with new parts.

Inspect the ball bearing used to support the accessory drive shaft shown in Fig. 6. Wash the bearing in clean fuel oil and dry it with compressed air. *Shielded bearings must not be washed*; dirt may be washed in and the cleaning fluid could not be entirely removed





7 - Former and Current Drive Plate Type Accessory Drive

e bearing. Wipe the outside of the bearing en hold the inner race and revolve the outer ly by hand. If the bearing is worn or does not y, replace the bearing.

he accessory drive hub, shown in Fig. 5, for at the area of contact with the lip of the oil the hub is grooved to a point where the ness of the oil seal is lost, a ring type oil seal available which serves to reposition the seal, viding a new sealing surface for the lip of the . 8).

ccessory Drive

ve old gasket material from the flywheel Use care so that no gasket material falls into train compartment.

a clean, lintless cloth in the flywheel housing to prevent bolts from accidentally falling in train. Align the bolt holes in the accessory te and spacer (if used), or the accessory drive the tapped holes in the camshaft or balance r. Then secure the plate and spacer, or drive four bolts (and lock washers or lock wire, if emove the cloth from the flywheel housing

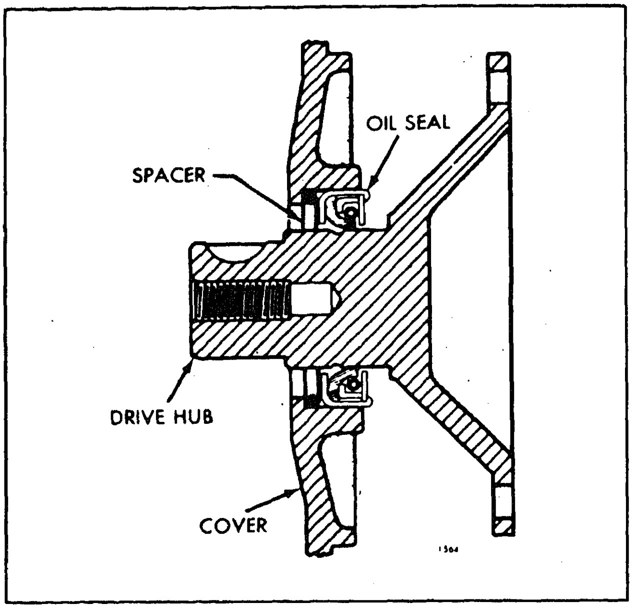


Fig. 8 - Location of Oil Seal Spacer

CAUTION: When replacing the drive hub on the accessory shaft, drive the hub squarely on the shaft (refer to Section 12.4).

a. Place a new gasket on the flange and align the holes in the gasket with the bolt holes in the flange. Use a light coat of grease to retain the gasket in position.

b. Place the accessory in position against the flywheel housing, rotating it, if necessary, to align the teeth of the accessory hub with those in the drive coupling. Secure the accessory to the flywheel housing with five bolts and lock washers.

4. If the accessory drive shown in Figs. 6 or 7 is used, assemble as follows:

a. Install the accessory drive plate and spacer as outlined in Steps 1 and 2 above.

b. Place the drive shaft retainer on the bed of an arbor press, with the mounting flange side up. Press the double row ball bearing straight in until the bearing contacts the shoulder in the bore of the retainer. Install the snap ring.

NOTE: On former accessory drives (Fig. 7), install the bearing with the protruding face of the inner race towards the retainer.

d. Turn the retainer over again, bearing side up, and press the accessory drive shaft in the bearing until the shoulder on the shaft contacts the bearing.

e. Apply a light coat of grease to the mounting flange of the retainer and place a new gasket in position against the flange. Align the holes in the gasket with the bolt holes in the flange.

f. Place the retainer and drive shaft assembly against the flywheel housing, rotating the shaft slightly, if necessary, to permit the teeth of the drive shaft to mesh with the teeth in the drive plate. Secure the retainer assembly to the flywheel housing with five bolts and lock washers.

g. On current accessory drives, install the spacer over the shaft and against the bearing.

h. Install the Woodruff key in the drive shaft. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.

i. Thread the pulley retaining nut on the end of the drive shaft and draw it up tight.

j. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.

NOTE: When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

5. Assemble the accessory drive shown in Fig. 5 a follows:

a. Press a new oil seal in the oil seal retainer, if th seal was removed.

b. Coat the mounting flange of the retainer lightl with grease and place a new gasket against th flange. Align the holes in the gasket with the bo holes in the flange.

c. With the accessory drive hub in place (see Step above), slip the retainer and oil seal assembl over the end of the shaft. Use care not to damag the oil seal. Secure the retainer to the flywhee housing with five bolts and lock washers.

d. Install the Woodruff key. Start the pulley straigh on the shaft, aligning the keyway in the pulle with the key on the shaft. Use a soft hammer t tap the pulley on the shaft.

e. Install the washers and the pulley retaining bol and draw the bolt up tight.

f. Install the accessory on the engine and slip th drive belt over the pulleys. Position the accessor to provide the proper tension on the belt an secure it in place.

NOTE: When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

ENGINE FRONT COVER (Upper)

In-Line Engines

The upper engine front cover is mounted against the cylinder block at the upper front end of the engine.

The camshaft and balance shaft oil seals (In-line engine) are pressed into the cover.

Remove Cover

When necessary, the oil seals may be removed without removing the upper front cover. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars. Install the new seals with installer J 9790.

If necessary, remove the engine cover as follows:

1. Remove the various parts and sub-assemblies from the engine as outlined in their respective sections of this manual.

2. Remove the pulleys from the front end of the camshaft and balance shaft (In-line engine). Refer to Section 1.7.2.

3. Remove the upper front cover-to-cylinder block attaching bolts.

4. Tap the cover and dowel pin assembly away f the cylinder block.

5. Remove the Woodruff keys and oil seal spa from the shafts.

6. Remove all traces of the old gasket material f the cylinder block and cover.

Inspection

Check the oil seals and the spacers for wear damage. Replace them if necessary.

Remove Oil Seals

1. Support the inner face of the cover on wood bl at least one inch thick to protect the dowel pins in cover.

2. Drive the oil seals out of the cover.

Install Oil Seals

1. Support the inner face of the cover on wood bloc

2. If the outside diameter of the oil seal is not coated with sealant, coat the bore in the cover non-hardening sealant.

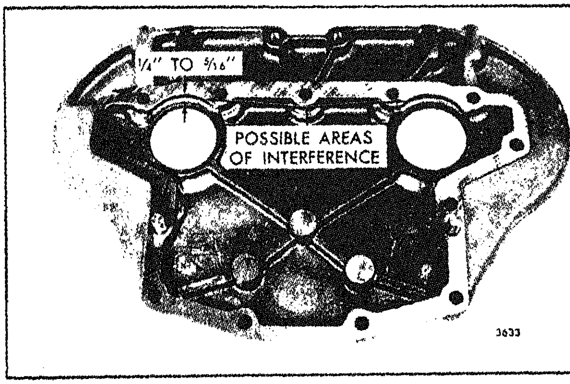


Fig. 2 · In-Line Engine Upper Front Cover

a new oil seal in the cover with the lip of nting toward the inner face of the cover.

N: Keep the lip of the oil seal clean and m scratches.

e seal into the cover with installer J 9790 seal is flush with the bottom of the e.

e second oil seal in the same manner.

excess sealant from the cover and the seals.

er

ew gasket to the cover.

ne cover on the engine and secure it with ock washers. Tighten the bolts to 35 lb-ft

3. Apply cup grease to the outside diameter of the oil seal spacers, then slide them on the shafts.

> **NOTE:** Current engines use an oil slinger between the oil seal spacer and the shoulder on the camshaft and between the spacer and the end bearing on the balance shaft (In-line engine). Addition of the oil slinger improves sealing by reducing the amount of oil in the area of the oil seals.

If oil slingers are installed on in-line engines built prior to Serial Number 3D-573 check the distance from the holes to the gasket flange (Fig. 2). If necessary, machine or grind the cover to provide sufficient clearance for the slingers.

4. Install a Woodruff key in each shaft.

5. Install the pulleys on the shafts.

6. Install and tighten the pulley retaining nuts to 300-325 lb-ft torque.

SHOP NOTES - TROUBLE SHOOTING - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

TEFLON WRAPPED PIPE PLUGS

Pipe plugs with a baked teflon coating are available for service. However, pipe plugs can be hand wrapped satisfactorily with teflon tape to provide a better seal and facilitate plug removal. When a teflon wrapped plug is installed, it is extremely important that the specified torque not be exceeded.

Hand wrap a pipe plug with teflon tape as follows:

1. Be sure the pipe plug is thoroughly clean and dry prior to applying the teflon tape. All dirt, grease, oil and scale must be removed.

2. Start the tape one or two threads from the sm leading edge of the plug, joining the tape tog with an overlap of approximately 1/8″.

3. Wrap the tape tightly in the same direction a would turn a nut. The tape must conform to configuration of the threads (be pressed into the r diameter of the threads) without cutting or rippin tape.

4. Hand tighten and hand torque the pipe plug ar *not exceed the specified torque. Do not use power to*

CHECKING BEARING CLEARANCES

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of .001″ to .003″, type PR-1 (red) has a range of .002″ to .006″ and type PB-1 (blue) has a range of .004″ to .009″.

The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and the crankshaft journal.

> **NOTE:** When checking the main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading, due to the weight of the crankshaft and flywheel, can be eliminated by supporting the weight of the crankshaft with a jack under the counterweight adjoining the bearing being checked.

2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4″ off center (Fig. 1).

3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

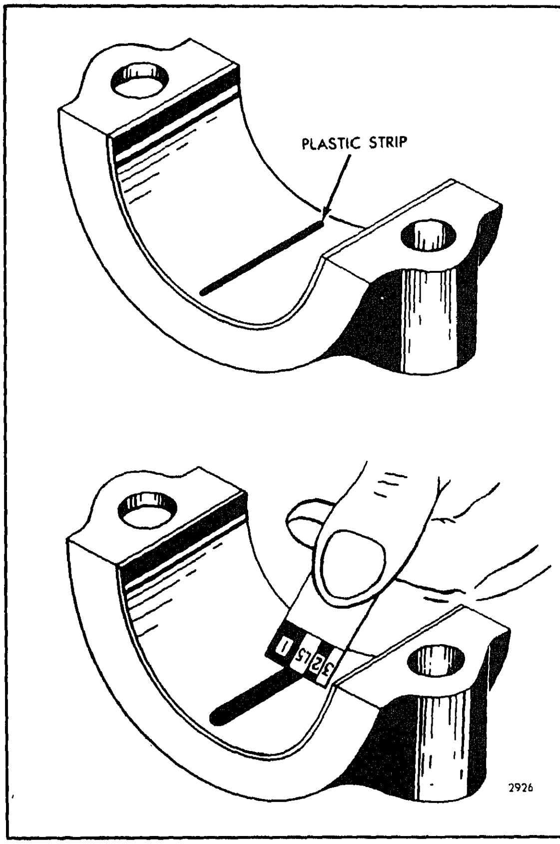


Fig. 1 - Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

he bearing cap. The flattened plastic strip
d adhering to either the bearing shell or
aft.

the width of the flattened plastic strip at
oint with the graduations on the envelope

(Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

CAMSHAFT CUP PLUG INSTALLATION

il leak occurs at the drive plug area in the
f the camshaft, install a cup plug in the end
shaft rather than removing and replacing
ug.

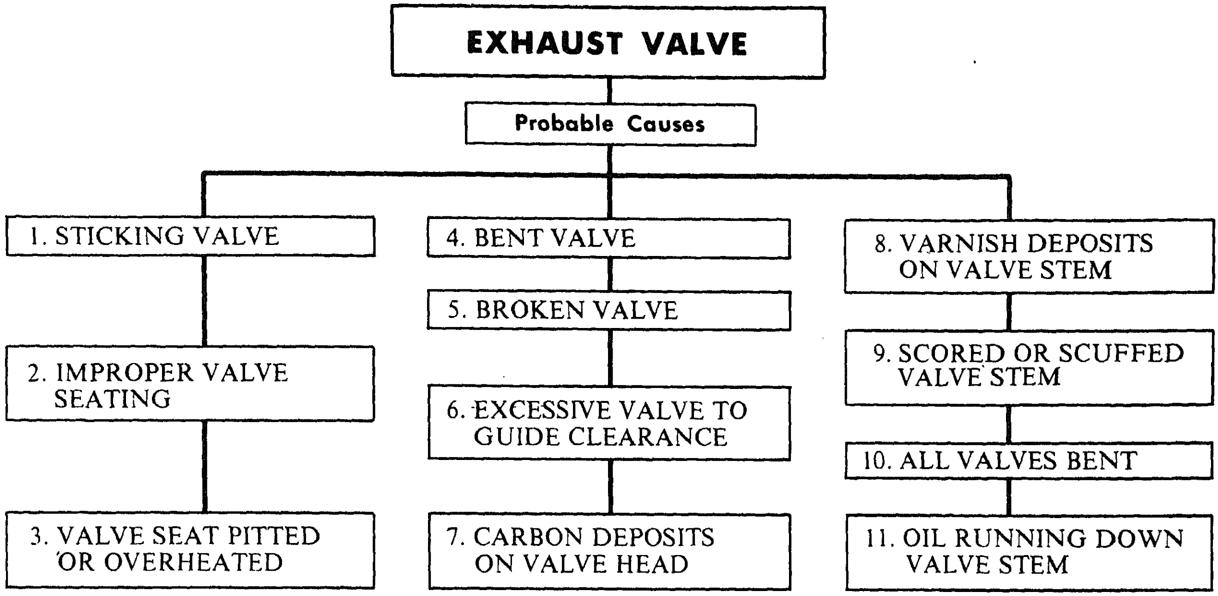
It is not necessary to remove the
t from the engine when installing the
.

Install the cup plug as follows:

1. Clean the hole in the front end of the camshaft and apply Permatex No. 1 sealant, or equivalent, to the outer diameter of the cup plug.

2. Install the plug to a depth of .180″-.210″ with tool J 24094.

TROUBLE SHOOTING



SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (glycol) in the lubricating oil. Replace a bent guide. Clean-up and reface the valve. Replace the valve if necessary.

2. Check for excessive valve-to-guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary.

3. Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder-face valve if operating conditions warrant.

4. Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge (four valve head) or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Replace damaged parts.

5. Check for excessive valve-to-guide clearance, defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder head and piston for damage. Replace damaged parts.

6. Replace a worn valve guide. Check and replace the valve, if necessary.

7. Black carbon deposits extending from the val seats to the guides indicates cold operation due to lig loads or to the use of too light a fuel. Rusty brov valve heads with carbon deposits forming narro collars near the guides indicate hot operation due overloads, inadequate cooling or improper timi which results in carbonization of the lubricating o Clean-up the valves, guides and inserts. Reface t valves and inserts or replace them if they are warpe pitted or scored.

8. Check for a worn valve guide or excessive exhau back pressure. Replace a worn guide. Check the val seat for improper seating. Reface the valve and inse or, if necessary, replace.

9. Check for a bent valve stem or guide, metal chips dirt, or for lack of lubrication. Clean up the valve ste with crocus cloth wet with fuel oil or replace the valv Replace the guide. When installing a valve, use care depressing the spring so that the spring cap DO NOT scrape the valve stem.

10. Check for a gear train failure or for improper ge train timing.

11. Check the operation of the engine for excess idling and resultant low engine exhaust back pressu Install valve guide oil seals.

SPECIFICATIONS

s, clearances and wear limits are listed hould be specifically noted that the pply only when all new parts are used at ere the various specifications apply. This to references within the text of the column entitled "Limits" in this chart unt of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Cylinder Block			
e:			
er (top)	4.5195″	4.5215″	4.5235″
er (center)	4.4865″	4.4880″	4.4900″
er (bottom)	4.3565″	4.3575″	4.3595″
ound		.0015″	.0020"
		.0015″	.0020"
ner counterbore:			
er	4.8200″	4.8350″	
	.3000″	.3020″	
ing bore:			
iameter (vertical axis, in-line engine)	3.2510″	3.2520″	
ce of block:			
--transverse (all)			.0030″
--longitudinal (3 cyl.)			.0060″
counterbores (top surface):			
head seal strip groove	.0970″	.1070″	
oles	.1090″	.1150″	
s	.0920″	.0980″	
Cylinder Liner			
iameter (upper seal ring surface)	4.4850″	4.4860″	
iameter (lower seal ring surface)	4.3550″	4.3560″	
meter	3.8752″	3.8767″	
nd (inside diameter)		.0020″	.0030″
ide diameter)		.0010″	.0020″
flange BELOW block	.0465″	.0500″	.0500″
in depth between adjacent liners		.0015″	.0015″

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Pistons and Rings			
Piston:			
Diameter (at skirt):			
Non-turbocharged engines	3.8699"	3.8721"	
Clearance--piston skirt-to-liner:			
Non-turbocharged engines	.0031"	.0068"	.0100"
Out-of-round		.0005"	
Taper		.0005"	
Inside diameter--piston pin bushing	1.3775"	1.3780"	
Compression rings:			
Gap (chrome ring)	.0200"	.0460"	.0600"
Gap (cast iron ring)	.0200"	.0360"	.0600"
Clearance--ring-to-groove:			
Top (No. 1)	.0030"	.0060"	.0120"
No. 2	.0070"	.0100"	.0140"
No. 3 and 4	.0050"	.0080"	.0130"
No. 3 and 4 (21:1 ratio piston)	.0045"	.0070"	.0120"
Oil control rings:			
Gap	.0100"	.0250"	.0440"
Clearance--ring-to-groove	.0015"	.0055"	.0080"
Piston Pins			
Diameter	1.3746"	1.3750"	
Clearance--pin-to-piston bushing	.0025"	.0034"	.0100"
Clearance--pin-to-conn. rod bushing	.0010"	.0019"	.0100"
Connecting Rod			
Length--center-to-center	8.7990"	8.8010"	
Inside diameter (upper bushing)	1.3760"	1.3765"	
Normal side clearance (in-line engine)	.0060"	.0120"	
Crankshaft			
Journal diameter--main bearing (in-line engine)	2.9990"	3.0000"	
Journal diameter--conn. rod bearing (in-line engine)	2.4990"	2.5000"	
Journal out-of-round		.00025"	
Journal taper		.0005"	.0030"
§Runout on journals--total indicator reading:			
3 cyl. in-line engine		.0020"	

§Runout tolerance given for guidance when regrinding crankshaft.

Crankshaft for 3-53 supported on No. 1 and No. 4 journals; runout me at No. 2 and No. 3 journals.

When the runout on adjacent journals is in the opposite direction, the sum must not exceed .003" total indicator r When in the same direction, the difference must not exceed .003" total indicator reading. When high spots of rur adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading, or .0 each journal.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
asher thickness	.1190″	.1220″	
(end thrust clearance)	.0040″	.0110″	.0180″
Connecting Rod Bearing			
ameter (vertical axis, in-line engine)	2.5015″	2.5035″	
o-journal clearance (in-line engine)	.0015″	.0045″	.0060″
thickness 90° from parting line (in-line)	.1245″	.1250″	.1230″
Main Bearings			
ameter (vertical axis, in-line engine)	3.0020″	3.0030″	
o-journal clearance (in-line engine)	.0010″	.0040″	.0060″
thickness 90° from parting line (in-line)	.1245″	.1250″	.1230″
Camshaft			
(at bearing journals)	2.1820″	2.1825″	
t center bearing (when mounted on end			
		.0020″	
st	.0050″	.0150″	.0190″
asher thickness	.2080″	.2100″	
Balance Shaft			
(at bearing journals)	2.1820″	2.1825″	
st	.0050″	.0150″	.0190″
asher thickness	.2080″	.2100″	
Camshaft and Balance Shaft Bearings			
ameter	2.1870″	2.1880″	
e--bearing-to-shaft	.0045″	.0060″	.0080″
Camshaft and Balance Shaft Gears			
	.0030″	.0050″	.0070″
Idler Gear (In-line Engines)			
	.0030″	.0050″	.0070″
bearing inside diameter	2.1860″	2.1870″	
hub outside diameter	2.1825″	2.1835″	
e--bearing-to-hub	.0025″	.0045″	.0070″
	.0060″	.0130″	.0170″
asher thickness	.1180″	.1200″	
Crankshaft Timing Gear			
	.0030″	.0050″	.0070″
meter (gear)	4.0580"	4.0590"	
ameter (crankshaft)	4.0600"	4.0610"	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Blower Drive Gear			
Backlash	.0030″	.0050″	.0070″
End play (blower drive gear shaft)	.0040″	.0060″	
Governor Drive Gear			
Backlash	.0030″	.0050″	.0070″
Cylinder Head			
Cam follower bore (current)	1.0626″	1.0636″	
Cam follower bore (former)	1.0620″	1.0630″	
Exhaust valve insert counterbore:			
Diameter (4-valve head)	1.1590″	1.1600″	
Exhaust Valve Seat Inserts			
Outside diameter (4-valve)	1.1605″	1.1615″	
Seat width	.0468″	.0781″	.0781″
Valve seat runout		.0020″	.0020″
Exhaust Valves			
Stem diameter (current 4-valve)	.2480″	.2488″	
Stem diameter (former 4-valve)	.2475″	.2485″	
Valve head-to-cylinder head:			
Current 4-valve head	flush	.024″ recess.	.039″ reces
Former 4-valve head	.006″ protr.	.018″ recess.	.033″ reces
Valve Guides			
Distance below top of head (plain guide)	.0100″	.0400″	
Distance below top of head (machined for seal)	.1900″	.2200″	
Diameter--inside (4-valve)	.2505″	.2515″	
Clearance--Valve-to-guide (current 4-valve)	.0017″	.0035″	.0050″
Clearance--Valve-to-guide (former 4-valve)	.0020″	.0040″	.0050″
Rocker Arms and Shafts			
Diameter--rocker shaft	.8735″	.8740″	
Diameter--inside (rocker arm bushing)	.8750″	.8760″	
Diameter--inside (valve rocker arm bore)	.8753″	.8763″	
Clearance--shaft-to-injector rocker bushing	.0010″	.0025″	.0040″
Clearance--shaft-to-valve rocker bore	.0013″	.0028″	.0040″
Cam Followers			
Diameter	1.0600″	1.0610″	
Clearance--follower-to-current head	.0016″	.0036″	.0060″
Clearance--follower-to-former head	.0010″	.0030″	.0060″
Rollers and pins:			
Clearance--pin-to-bushing	.0013″	.0021″	.010″ Hori
Side clearance--roller-to-follower	.0150″	.0230″	.0230″

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

EAD E	TORQUE (lb-ft)	THREAD SIZE	TORQUE (lb-ft)
-20	7-9	9/16-12	90-100
-28	8-10	9/16-18	107-117
-18	13-17	5/8 -11	137-147
-24	15-19	5/8 -18	168-178
-16	30-35	3/4 -10	240-250
-24	35-39	3/4 -16	290-300
-14	46-50	7/8 - 9	410-420
-20	57-61	7/8 -14	475-485
-13	71-75	1 - 8	580-590
-20	83-93	1 -14	685-695

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

LICATION	THREAD SIZE	TORQUE (lb-ft)
tor control shaft bracket bolts	1/4 -20	10-12
follower guide bolts	1/4 -20	12-15
ernor to flywheel housing bolts	5/16-18	10-12
gear hub and spacer bolts	5/16-18	19-23
oan bolts	5/16-18	10-12
gear hub and spacer bolts	3/8 -16	40-45
tor clamp bolts	3/8 -16	20-25
oox cover bolts (in-line engine)	3/8 -16	12-16
heel housing bolts	3/8 -16	25-30
heel housing bolts	3/8 -24	25-30
necting rod nuts (in-line engine)	3/8 -24	40-45
line nuts	3/8 -24	12-15
connector	3/8 -24	20-28
ker arm bracket bolts	7/16-14	50-55
wheel bolts	1/2 -20	110-120
in bearing cap bolts	9/16-12	120-130
inder head bolts	5/8 -11	170-180
ge mounted air compressor drive shaft nut	3/4 -10	§
kshaft end bolt (in-line engine)	3/4 -16	290-300
compressor drive pulley nut	3/4 -16	80-100
kshaft end bolt (engines with cone mounted pulley amped with letter "A"	1 -14	200-220
shaft and balance shaft nut	1-1/8 -18	300-325

ate at assembly with international Compound No. 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12.8000A).
-ft plus increase torque to line-up cotter pin.

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or Teflon. These specifications apply to plugs installed below the sur the part of which they are a component.

THREAD SIZE	TORQUE (lb-ft)	THREAD SIZE	TORQ (lb-
1/8	10-12	3/4	33-
1/4	14-16	1	75-
3/8	18-22	1-1/4	95-
1/2	23-27	1-1/2	110-

SERVICE TOOLS

TOOL NAME	TOOL NO.
Cylinder Block	
Bore gage	J 5347
Dial bore gage master setting fixture	J 23059
Dial indicator set	J 22273
Engine overhaul stand	J 6837-01
Adaptor plate (In-line)	J 7622
Cylinder Head	
Brush	J 8152
Cam follower holding fixture	J 5840
Cylinder head guides (set of 2)	J 9665
Cylinder head lifter	J 22062-01
Dial gage (4 - valve head)	J 8165-2
Grinder (4 - valve head)	J 8165-1
Grinding wheel (15° 4 - valve head)	J 7792-2
Grinding wheel (30° 4 - valve head)	J 7792-3
Grinding wheel (60° 4 - valve head)	J 7792-4
Pilot (4 - valve head)	J 7792-1
Push rod remover (set of three)	J 3092-01
Socket	J 8932-01
Spring tester	J 9666
Valve guide cleaner (4 - valve head)	J 7793
Valve guide installer (15° 4 - valve head)	J 7832
Valve guide installer (45° 4 - valve head)	J 9729
Valve guide installer (guide used with oil seal - 4 valve head)	J 9730

L NAME	TOOL NO.
e guide remover (4 - valve head)	J 7775
e spring checking gage	WRE 500-60
e spring compressor (4 - valve head)	J 7455
e seat insert installer (4 - valve head)	J 7790
e seat insert remover (4 - valve head)	J 7774
kshaft	
shaft oil seal installer	J 21899
kshaft front oil seal installer	J 22153
kshaft front oil seal sleeve installer (in-line)	J 22524
kshaft pulley installer	J 7773
kshaft pulley remover	J 5356
kshaft rear oil seal (O.S.) expander	J 21278
kshaft rear oil seal sleeve installer	J 21277
dle	J 3154-1
ometer ball attachment	J 4757
eal expander	J 9769
eal expander (in-line)	J 7454
eal installer	J 9479
nstaller (part of J 9479)	J 9479-1
Stud (2) (part of J 9479)	J 9479-2
eal installer	J 9727
eal installer	J 9783
r	J 4794-01
heel	
heel lifting tool	J 6361-01
heel Housing	
kshaft rear oil seal expander (O.S. seal)	J 21278
kshaft rear oil seal expander (Std. size seal)	J 9769
indicator	J 8001-3
indicator post	J 9748
heel housing aligning studs (set of 2)	J 7540
heel housing concentricity gage	J 9737

TOOL NAME	TOOL NO.
Piston, Connecting Rod and Cylinder Liner	
Adaptor sleeve	J 7608-5
Bore gage	J 5347
Connecting rod bushing reamer	J 4971-4
Connecting rod bushing reamer set	J 7608-01
Connecting rod holder	J 7632
Cylinder hone set (2 1/2" to 5 3/4" range)	J 5902-01
Cylinder liner remover set	J 22490
Dial bore gage master setting fixture	J 23059
Dial indicator set	J 22273
Driver handle	J 1513-2
Feeler gage pack (part of J 5438)	J 3174-01
Fixture and arbor assembly	J 7608-4
Guide	J 1686-5
Guide	J 4970-5
Guide	J 4971-6
Hold down clamp	J 21793
Master ring - cylinder liner	J 8385
Micrometer ball attachment	J 4757
Piston and connecting rod bushing installer and remover set	J 1513-02
Piston bushing reamer	J 4970-4
Piston bushing reaming fixture	J 5273
Piston bushing spacer	J 7587-1
Piston holding fixture	J 1513-1
Piston pin bushing installer	J 4972-2
Piston pin bushing remover	J 4972-4
Piston pin retainer installer	J 23762
Piston ring compressor	J 6883
Piston ring remover and installer	J 8128
Piston-to-liner feeler gage set	J 5438
Spacer	J 7608-3
Spray nozzle remover	J 8995
Spring scale (part of J 5438)	J 8129
Stone (120 grit)	J 5902-14
Camshaft	
Adaptor	J 8183
Bar type puller	J 4871
Camshaft and balance shaft bearing remover and installer set	J 7593-03
Camshaft cup plug installer	J 24094
Camshaft oil seal installer	J 21899
Crankshaft timing gear installer	J 7557
Installer	J 9790
Slide hammer	J 6471-1
Spring scale	J 8129

SECTION 2

FUEL SYSTEM AND GOVERNORS

CONTENTS

FUEL SYSTEM

The fuel system (Fig. 1) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and fuel lines.

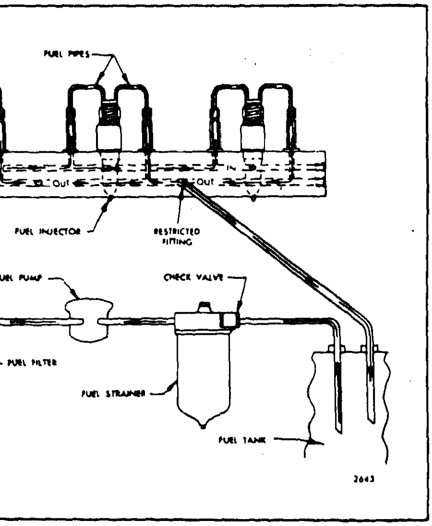
Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each injector.

The fuel manifolds are identified by the words **IN** (top passage) and **OUT** (bottom passage) which are ca several places in the side of the cylinder head. aids installation of the fuel lines.

Surplus fuel returns from the outlet side of injectors to the fuel return manifold and then ba the supply tank.

All engines are equipped with a restrictive fittin the fuel outlet manifold to maintain the fuel sy pressure.

Refer to Section 13.2 for the size fitting required.



Typical Fuel System for In-Line Engines

may be installed in the supply line l tank and the fuel strainer to prevent ng back when the engine is shut down.

FUEL INJECTOR (NEEDLE VALVE)

The fuel injector (Figs. 1 and 2) is a lightweight compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

The fuel injector performs four functions:

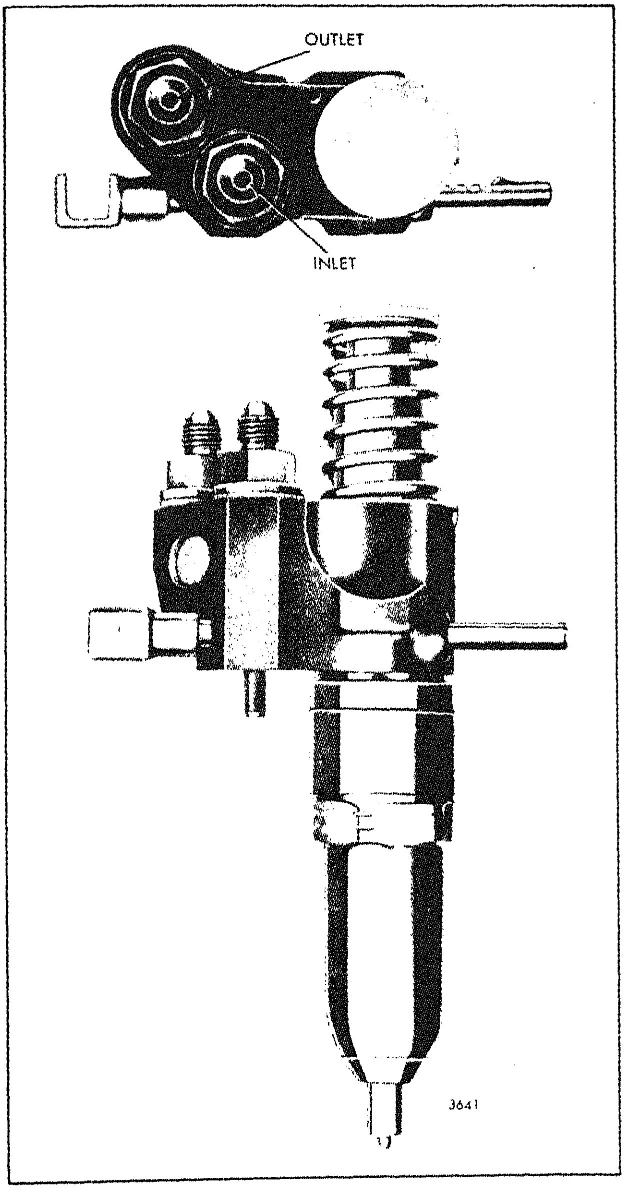


Fig. 1 · Fuel Injector Assembly

1. Creates the high fuel pressure required for effi
injection.

2. Meters and injects the exact amount of fuel requ
to handle the load.

3. Atomizes the fuel for mixing with the air in
combustion chamber.

4. Permits continuous fuel flow.

Combustion required for satisfactory engine opera
is obtained by injecting, under pressure, a s
quantity of accurately metered and finely atom
fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper
lower helix machined in the lower end of the inje
plunger. Figure 3 illustrates the fuel metering f
no-load to full-load by rotation of the plunger in
bushing.

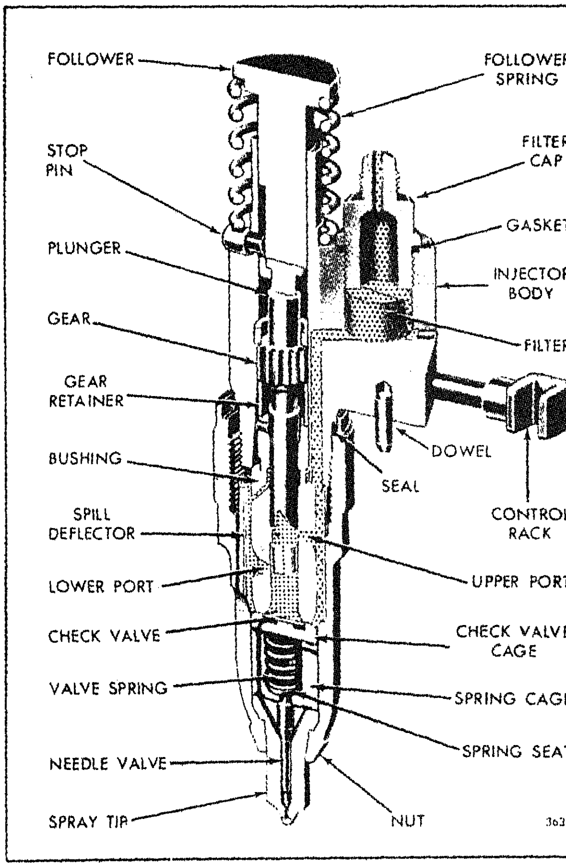
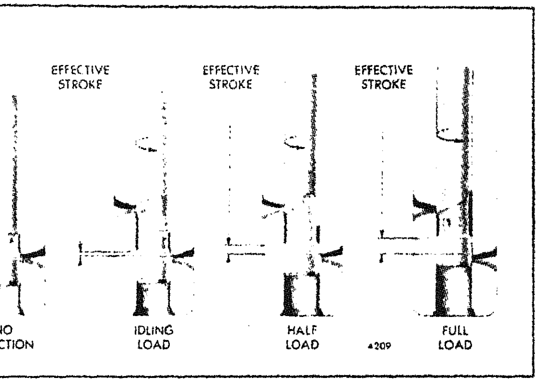


Fig. 2 · Cutaway View of Fuel Injector



ig. 3 - Fuel Metering from No-Load to Full-Load

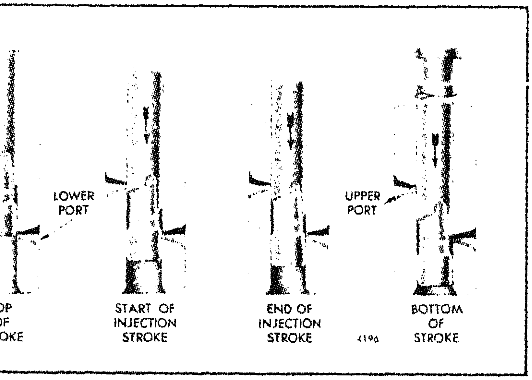
4 illustrates the phases of injector operation by tical travel of the injector plunger.

ntinuous fuel flow through the injector serves, lition to preventing air pockets in the fuel as a coolant for those injector parts subjected combustion temperatures.

y the power output of the engine, injectors different fuel output capacities are used. The tput of the various injectors is governed by the ngle of the plunger and the type of spray tip Refer to Fig. 5 for the identification of the rs and their respective plungers and spray tips.

he helix angle on the plunger determines the and operating characteristics of a particular f injector, it is imperative that the correct rs are used for each engine application. If rs of different types are mixed, erratic operation ult and may cause serious damage to the engine e equipment which it powers.

JTION: Do not intermix the needle valve injectors with the other types of injectors in an engine.

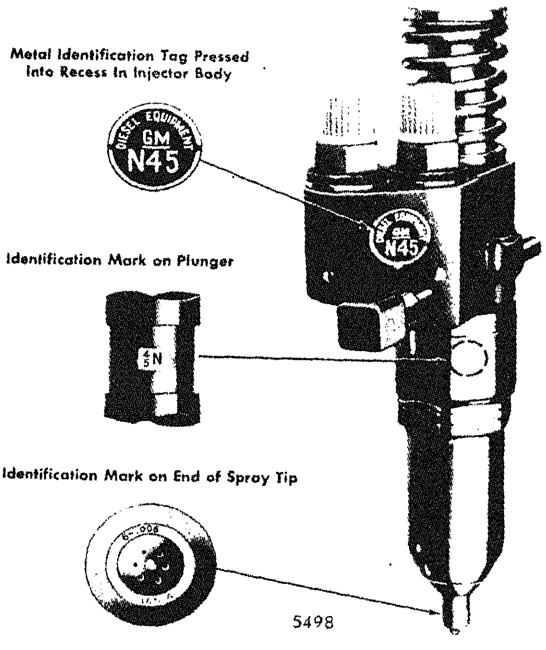


. 4 - Phases of Injector Operation Through Vertical Travel of Plunger

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 5). The identification tag indicates the nominal output of the injector in cubic millimeters.

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.



INJECTOR	SPRAY TIP*	PLUNGER
N45	6-006-165A	4/5 N

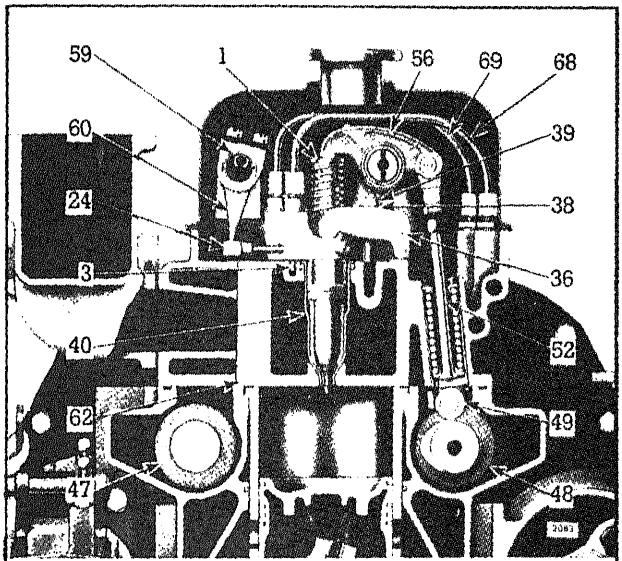
Fig. 5 - Injector Identification Chart

Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber



1. Injector Assembly	49. Cam Follower Assy.
3. Pin--Dowel	52. Rod--Push
24. Rack--Injector Control	56. Arm--Injector Rocker
36. Clamp--Injector	59. Tube--Injector Control
38. Washer	60. Lever--Rack Control
39. Bolt	62. Head--Cylinder
40. Tube--Injector Hole	68. Pipe--Fuel Inlet (Supply)
47. Shaft--Balance	69. Pipe--Fuel Outlet (Return)
48. Camshaft	

Fig. 6 - Fuel Injector Mounting

through the lower port until the port is cl the lower end of the plunger. A portion c trapped below the plunger is then forced up central passage in the plunger into the fue recess and into the supply chamber through port until that port is closed off by the upp the plunger. With the upper and lower closed off, the remaining fuel under the subjected to increased pressure by the downward movement of the plunger.

When sufficient pressure is built up, it ope non-return check valve. The fuel in the c cage, spring cage, tip passages and tip fue compressed until the pressure force acting the needle valve is sufficient to open the val the downward force of the valve spring. As s needle valve lifts off of its seat, the fuel through the small orifices in the spray atomized into the combustion chamber.

When the lower land of the plunger un lower port in the bushing, the fuel pressure plunger is relieved and the valve spring needle valve, ending injection.

A pressure relief passage has been provid spring cage to permit bleed-off of fuel leakin needle pilot in the tip assembly.

A check valve, directly below the bushing leakage from the combustion chamber int

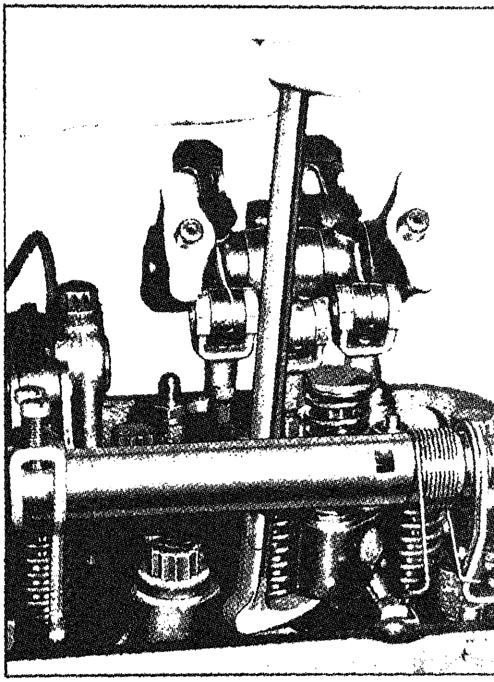
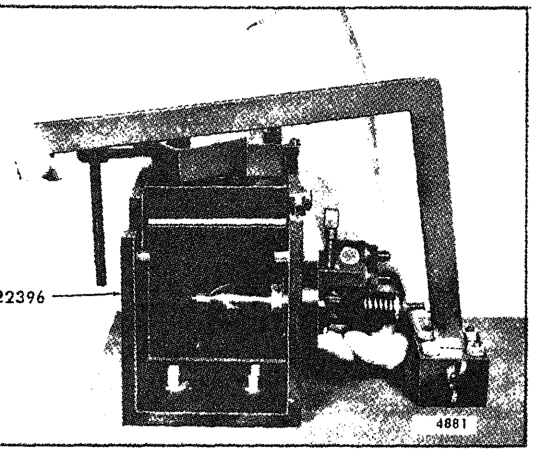


Fig. 7 - Removing Injector from Cylinder



ig. 8 - Checking Rack and Plunger for Free Movement

r in case the valve is accidentally held open by a particle of dirt. The injector plunger is then ed to its original position by the injector er spring. Figure 4 shows the various phases of r operation by the vertical travel of the injector r.

e return upward movement of the plunger, the oressure cylinder within the bushing is again with fuel oil through the ports. The constant tion of fresh cool fuel through the injector the fuel supply in the chamber, helps cool the r and also effectively removes all traces of air might otherwise accumulate in the system and re with accurate metering of the fuel.

uel injector outlet opening, through which the fuel oil returns to the fuel return manifold and ack to the fuel tank, is directly adjacent to the pening.

ing the position of the helices, by rotating the r, retards or advances the closing of the ports e beginning and ending of the injection period. same time, it increases or decreases the amount injected into the cylinder. Figure 3 shows the s plunger positions from no-load to full-load. the control rack pulled out all the way (no on), the upper port is not closed by the helix fter the lower port is uncovered. Consequently, e rack in this position, all of the fuel is forced nto the supply chamber and no injection of fuel place. With the control rack pushed all the way injection), the upper port is closed shortly after ver port has been covered, thus producing a um effective stroke and maximum injection. this no injection position to full injection n (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air. Also provide a source for 110 volt alternating current electric power.

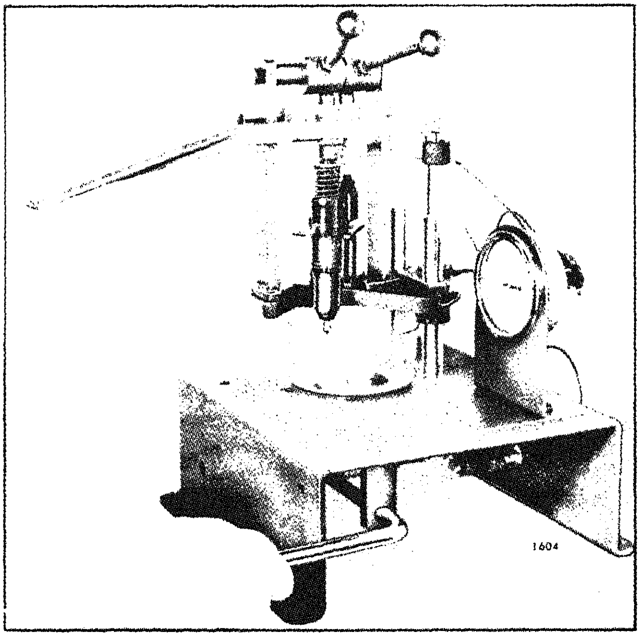


Fig. 9 - Injector High Pressure Test

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning agent, usually clean fuel oil, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free cleaning tissue is a good, inexpensive material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors. Also protect the fuel pipes and fuel connectors from the entry of dirt or other foreign material.

2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and assembly of an injector.

NOTE: In the offset injector, a filter is used in the inlet side only. No filter is required o[n the] outlet side (Fig. 34).

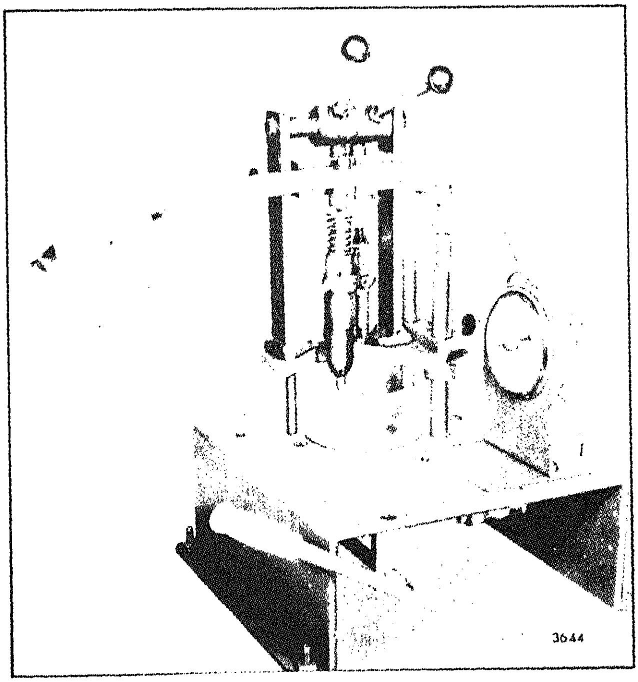


Fig. 10 - Spray Pattern Test

3. Whenever an injector has been remov[ed and] reinstalled or replaced in an engine, m[ake the] following adjustments as outlined in Section 1[4]

a. Time the injector.

b. Position the injector control rack.

4. Whenever an engine is to be out of servic[e for an] extended period, purge the fuel system, then fi[ll with] a good grade of rust preventive (refer to Sectio[n

5. When a reconditioned injector is to be p[laced in] stock, fill it with injector test oil J 8130. *Do not* [...] *oil.* Install shipping caps on both filte[r caps] immediately after filling. Store the injecto[r in an] upright position to prevent test oil leakage.

NOTE: Make sure that new filters have [been] installed in a reconditioned injector which [is to] be placed in stock. This precaution will pre[vent] dirt particles from entering the injector due [to] possible reversal of fuel flow when insta[lling] the injector in an engine other than the orig[inal] unit.

Remove Injector

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from both the injec[tor and] the fuel connectors (Fig. 6).

NOTE: Immediately after removal of the [fuel] pipes from an injector, cover the filter caps [with] shipping caps to prevent dirt from enterin[g the] injector. Also protect the fuel pipes and [...]

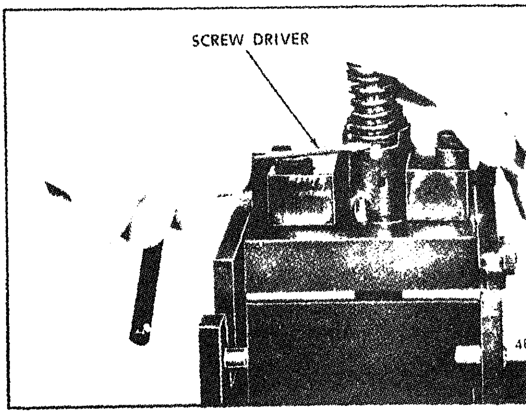


Fig. 11 - Removing Injector Follower Stop

nectors from entry of dirt or foreign terial.

nk the engine to bring the outer ends of the ods of the injector and valve rocker arms in line ntally.

nove the two rocker shaft bracket bolts and the rocker arms away from the injector and (Fig. 7).

nove the injector clamp bolt, special washer and

sen the inner and outer adjusting screws on the r rack control lever and slide the lever away ne injector.

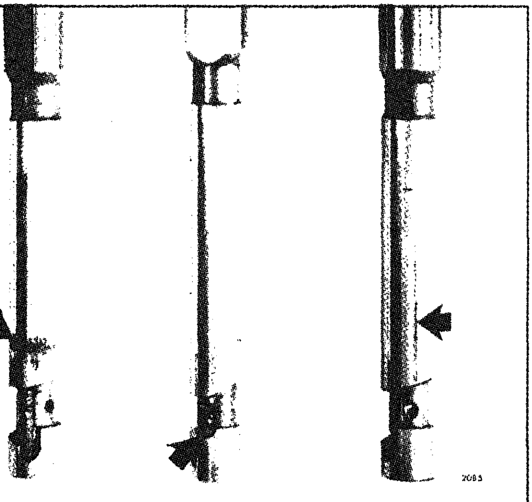
the injector from its seat in the cylinder head).

er the injector hole in the cylinder head to keep material out.

n the exterior of the injector with clean fuel oil y it with compressed air.

jector

ection does not reveal any external damage, perform a series of tests to determine the on of the injector to avoid unnecessary uling.



nced stage of on caused by n matter in ue to improper ion.

Chipped at lower helix.

The above condition can be caused by either lack of fuel at high speeds or water in fuel.

Fig. 12 - Unusable Injector Plungers

An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails to pass one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure drop and fuel output as indicated by the following tests:

INJECTOR CONTROL RACK AND PLUNGER MOVEMENT TEST

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.

With the injector control rack held in the no-fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the follower reaches the top of its travel. If the rack does

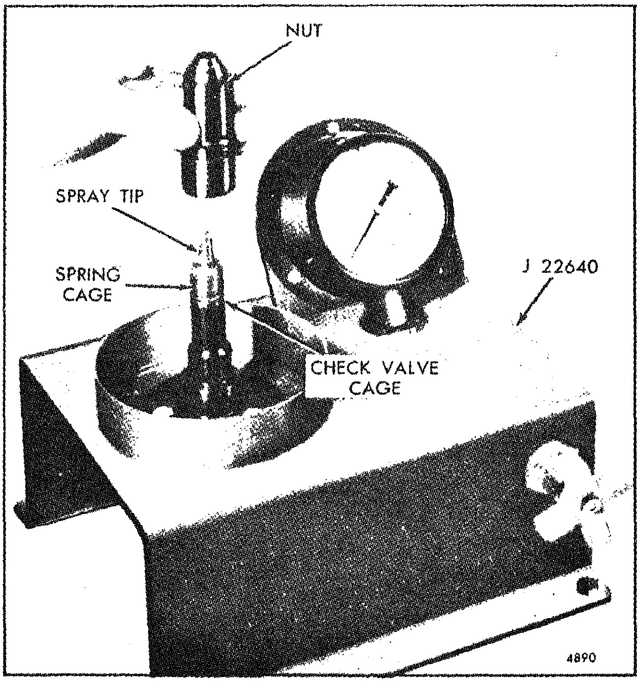


Fig. 13 - Installing Injector Valve Parts on Auxiliary Tester J 22640

not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times if necessary. Generally this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts.

INJECTOR HIGH PRESSURE TEST

This test is performed to discover any fuel leaks at the injector filter cap gaskets, body plugs and nut seal ring.

The high pressure test also indicates whether or not the plunger and bushing clearance is satisfactory.

1. Install the injector in tester J 9787.

> **CAUTION:** When testing an injector just removed from an engine, the flow of fuel through the injector on the tester should be the same as in the engine. Connections on the test head of the tester may be changed to obtain the correct direction of flow.

2. Thoroughly dry the injector with compressed air.

3. Check the fuel connections for leaks. If leaks have occurred, tighten the connections, dry the injector and recheck.

4. With the injector rack in the full-fuel position and the injector tester handle locked in position by means of the handle lock (Fig. 9), operate the pump handle to build up and maintain the pressure.

At this time, the condition of the plunger and bushing may be established. If there is excessive clearance between the plunger and bushing, pressure beyond the normal valve opening pressure cannot be obtained. Replacement of the plunger and bushing assembly is then required.

Pump up the injector tester and maintain a pressure of 1600 to 2000 psi by actuating the pump handle. Then inspect for leaks at the injector filter cap gaskets, body plugs and injector nut seal ring. If any of these conditions exist, refer to *Trouble Shooting Chart* 5 in Section 2.0.

> **NOTE:** It is normal for fuel to seep out around the rack due to high pressure fuel being applied to a normally low pressure area in the injector assembly. However, fuel droplets at the rack indicate excessive leakage.

> **CAUTION:** Do not permit the pressure in the

injector tester to equal or exceed the capacit[y of] the pressure gage.

INJECTOR VALVE HOLDING PRESSURE TEST

The injector valve holding pressure test will det[ermine] whether the various lapped surfaces in the injec[tor are] sealing properly.

Operate the pump handle to bring the pressure [up to] approximately 450 psi.

Close the fuel shut-off valve and note the p[ressure] drop. The time for a pressure drop from 450 psi [to ...] psi must not be less than 40 seconds. If the p[ressure] drop is less than 40 seconds, check the injec[tor as] follows:

1. Thoroughly dry the injector with compressed [air].

2. Open the tester fuel valve and operate the [pump] handle to maintain the test pressure.

3. A leak around the spray tip or seal ring usu[ally is] caused by a loose injector nut, a damaged seal [ring or] a brinelled surface on the injector nut or spray t[ip].

4. A leak at the filter cap indicates a loose filter [cap or] a damaged filter cap gasket.

5. A "dribble" at the spray tip orifices indic[ates a] leaking valve assembly due to a damaged surf[ace or] dirt. Leakage at the tip will cause pre-ignition [in the] engine.

> **NOTE:** A drop or two of fuel at the spray ti[p is] only an indication of the fuel trapped in [the] spray tip at the beginning of the test and is [not] detrimental as long as the pressure d[rop] specified is not less than 40 seconds.

SPRAY PATTERN TEST

After completing the valve holding pressure tes[t, open] the fuel shut-off valve, place the injector rack [in the] full-fuel position and operate the injector severa[l times] in succession by operating the tester han[dle at] approximately 40 strokes per minute as sho[wn in] Fig. 10. Observe the spray pattern to see that al[l spray tip] orifices are open and injecting evenly. The beg[inning] and ending of injection should be sharp and t[he fuel] injected should be finely atomized.

If all of the spray tip orifices are not ope[n and] injecting evenly, clean them during injector ov[erhaul]. Also refer to *Trouble Shooting Chart* 6 in Sectio[n ...]

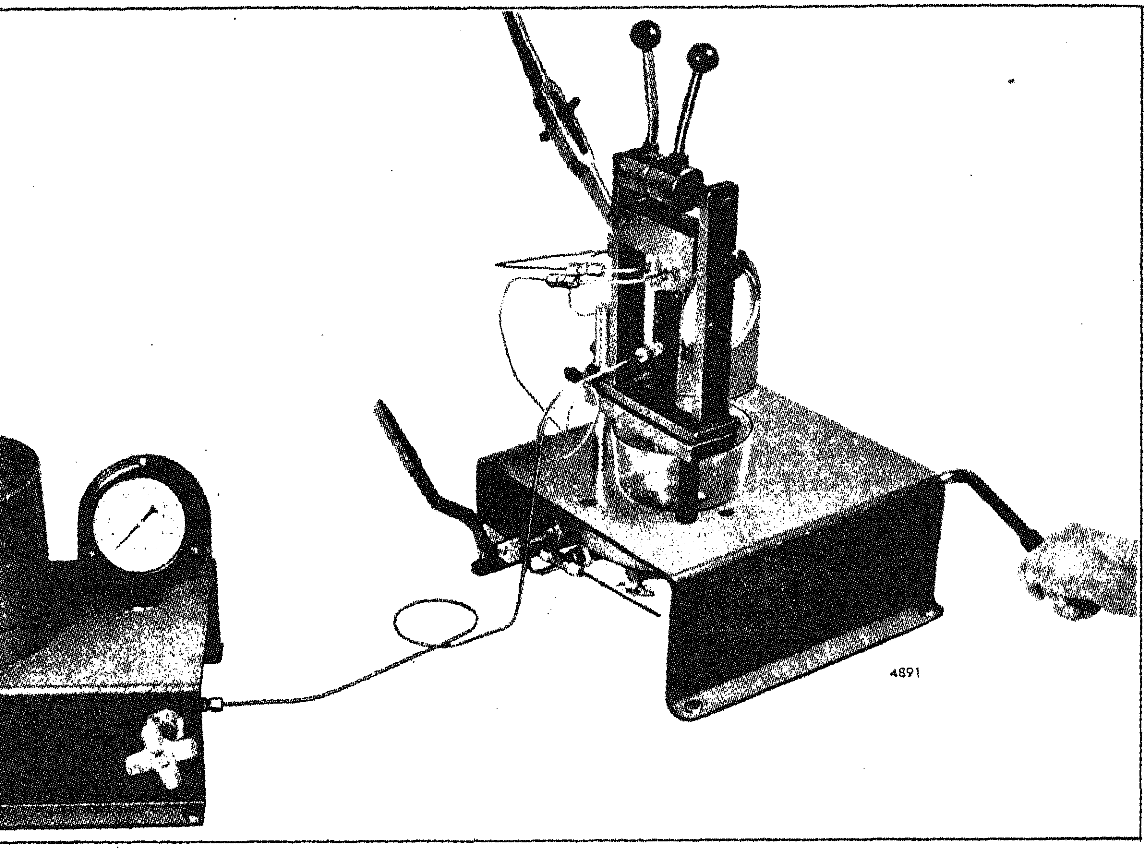
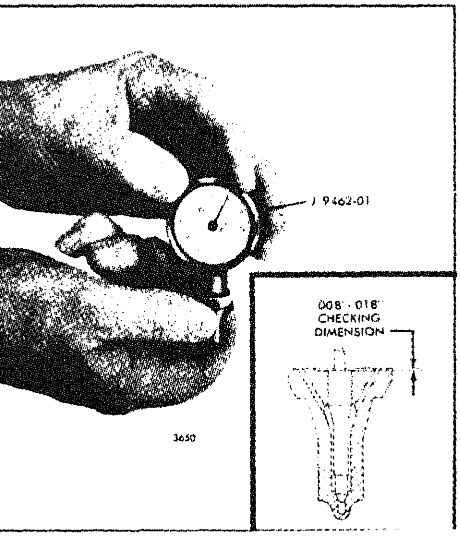


Fig. 14 · Injector Needle Valve Test with Auxiliary Tester J 22640

To prevent damage to the pressure
ot exceed 100 psi during this test.



15 · Checking Needle Valve Lift

VISUAL INSPECTION OF PLUNGER

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests.

Remove the plunger from the injector as follows:

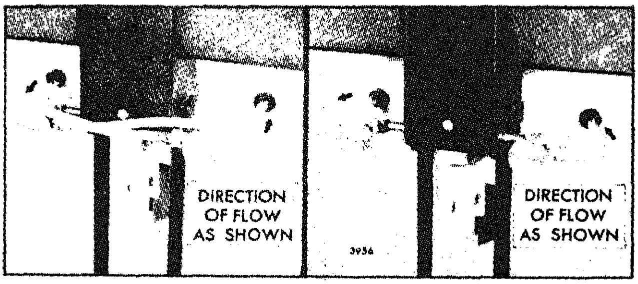


Fig. 16 · Position of Fuel Flow Pipes in Comparator

1. Support the injector, right side up, in holding fixture J 22396.

2. Compress the follower spring. Then raise the spring above the stop pin with a screw driver and withdraw the pin (Fig. 11). Allow the spring to rise gradually.

3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.

4. Inspect the plunger. If the plunger is chipped (Fig. 12), replace the plunger and bushing assembly.

5. Reinstall the plunger, follower and spring.

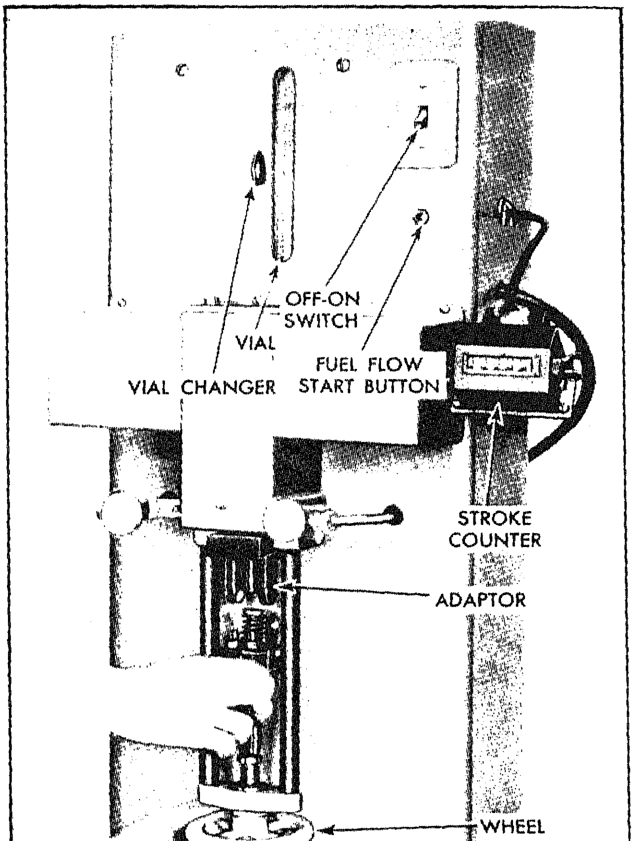


Fig. 17 · Placing Injector in Comparator J 7041

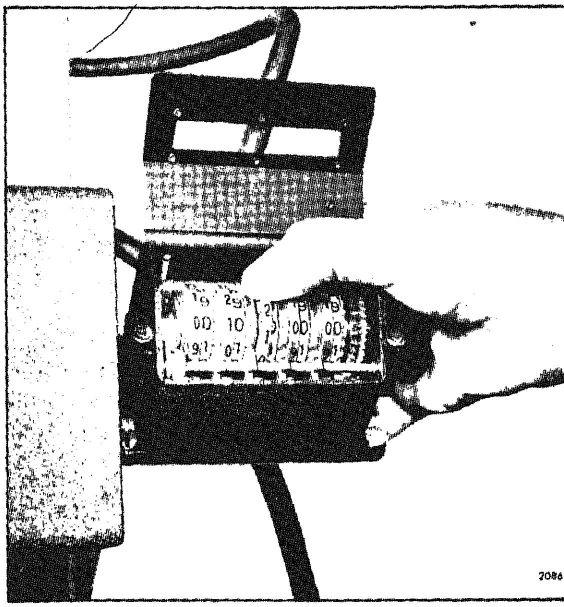


Fig. 18 · Setting Comparator Stroke Counter

NEEDLE VALVE TESTS

Remove the injector nut and remove all of the p below the injector bushing as outlined u *Disassemble Injector.*

Clean all of the carbon off of the spray tip seat in injector nut as outlined under *Clean Injector Parts.*

If the spray pattern test indicated that tip cleanin necessary, clean the carbon from the tip cavity b the needle valve and orifices as outlined under *C Injector Parts.*

With the injector nut and spray tip cleaned, asse the check valve, check valve cage, spring, spring spring cage, needle valve and tip assembly auxiliary tester J 22640 (Fig. 13). Carefully pilo injector nut over the spray tip and valve parts thread it on the body as shown in Fig. 13. Tighter injector nut to 75-85 lb-ft torque.

Install the shield in the auxiliary tester as show Fig. 14 and operate the pump handle until the s tip valve has opened several times to purge th from the system.

Operate the pump handle with smooth even st (40 strokes per minute) and note the pressure at w the needle valve opens. The valve should open bet 2300 and 3300 psi. The opening and closing a should be sharp and produce a finely atomized spr

If the valve opening pressure is below 2300 psi ar

oor, the cause usually is a worn or ring. Replace the spring.

ning pressure is within 2300-3300 psi, k for spray tip seat leakage. Actuate e several times, then hold the pressure 15 seconds. Inspect the spray tip seat re should be no fuel droplets although g of the end of the valve tip is

seat is satisfactory, proceed to check a pressure drop of from 1500 to 1000 ould not be less than 5 seconds. If the ops from 1500 to 1000 psi in less than e the needle valve and tip assembly.

ve assembly passes the above test, the check can be omitted. To check the t , use tool J 9462-01 (Fig. 15) as

ator by placing the bottom surface of mbly on a flat surface and zero the

y tip and needle valve assembly tight om of the gage with the quill of the ne hole in the plunger.

g the spray tip and needle valve gainst the gage, read the needle valve cator. The lift should be .008 " to eds .018 ", the tip assembly must be less than .008 ", inspect for foreign the needle valve and the tip seat.

valve lift is within the limits, install a spring and recheck the valve opening re action. Low valve opening pressure ation with a new spring and seat y tip and needle valve assembly must

Calibrator J 22410		Comparator J 7041	
Min.	Max.	Min.	Max.
47	51	14	20

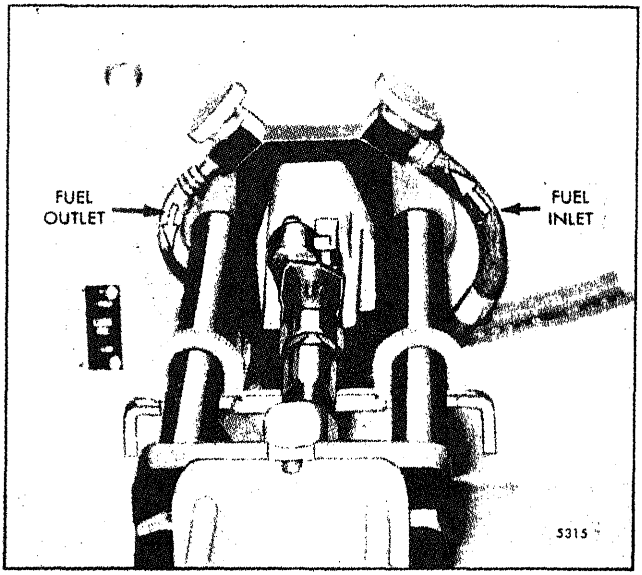


Fig. 20 - Position of Calibrator Fuel Flow Pipes

Reassemble the injector as outlined under *Assemble Injector* and check it in the comparator or the calibrator.

FUEL OUTPUT TEST

The injector fuel output test can be performed in either the comparator J 7041 or the calibrator J 22410.

When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine, note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the fuel pipes on the comparator (Fig. 16) depends on the adaptor being used and the direction of fuel flow through the injector. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the calibrator (Fig. 20) depends on the adaptor being used and the direction of fuel flow through the injector.

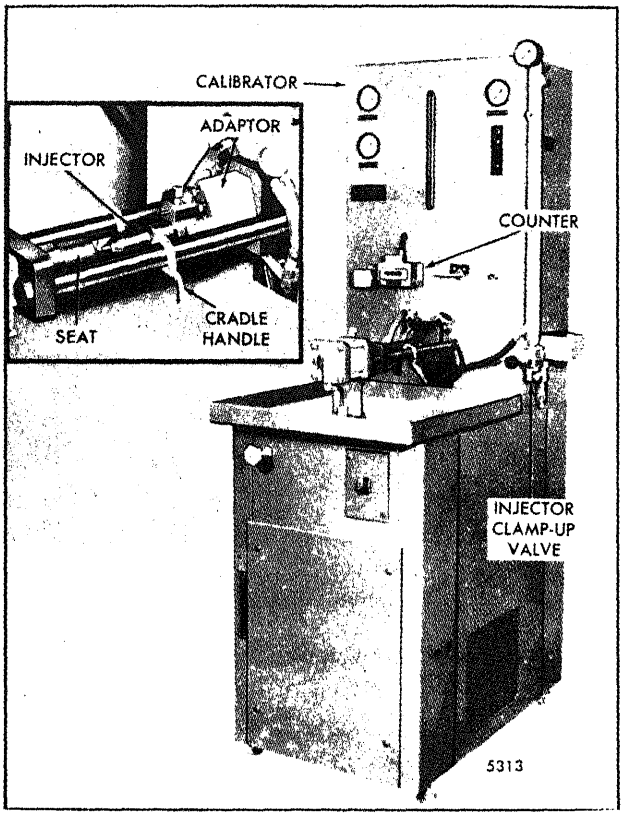


Fig. 21 · Injector in Calibrator J 22410

COMPARATOR J 7041

To check the fuel output, operate the injector in the comparator (Fig. 17) as follows:

1. Place the injector in the comparator and tighten the hand wheel to clamp the injector and adaptor in position.

> **IMPORTANT:** Make sure the counter on the comparator is preset to 1000 strokes. If, for any reason, this setting has been altered, raise the cover and reset the counter to 1000 strokes by pulling the selector wheel to be changed to the right and rotating it to its proper setting (Fig. 18). Then release the wheel and close the cover. Refer to the comparator instruction booklet for further information.

> **NOTE:** When installing a low clamp body injector in the comparator, position the injector in the adaptor at approximately a 45 ° angle, rather than straight into the adaptor, then bring it into a vertical position and secure it in place.

2. Pull the injector rack out to the no-fuel position.

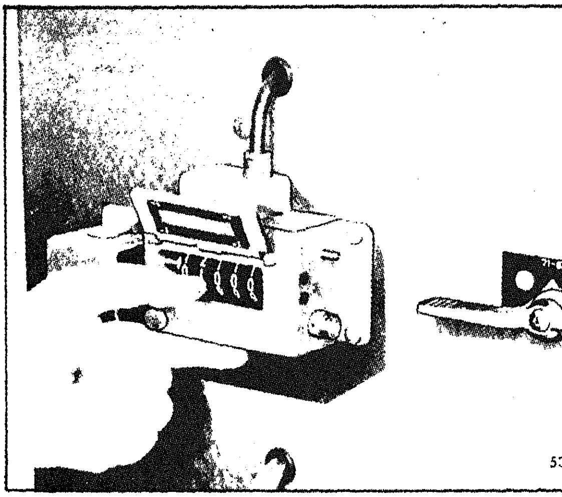


Fig. 22 · Setting Calibrator Stroke Counter

3. Start the comparator by turning on the switch.

4. After the comparator has started, push the inj rack in to the full-fuel position.

5. Let the injector run for approximately 30 secon purge the air that may be in the system.

6. After 30 seconds, press the fuel flow start bu This will start the flow of fuel into the vial.

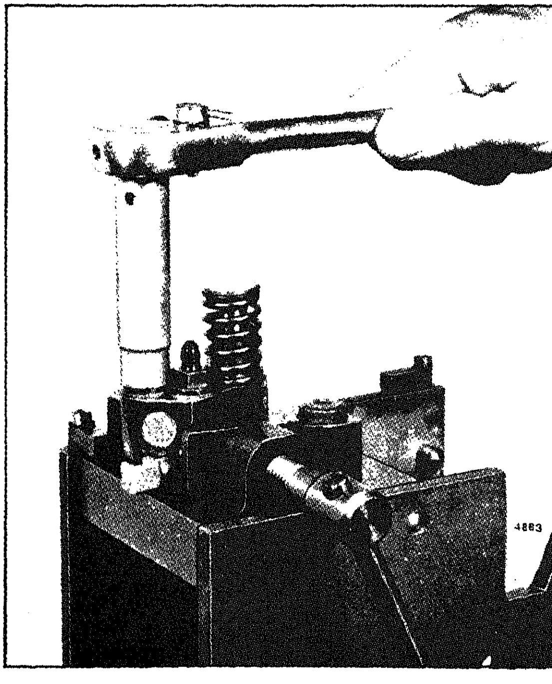


Fig. 23 · Removing or Installing Filter Cap

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

> **CAUTION:** Do not buff excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

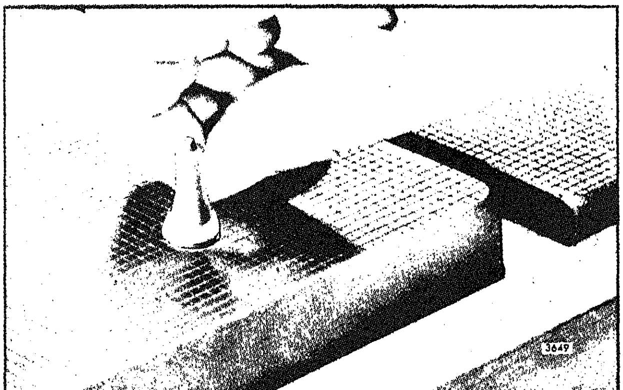
When the body of the spray tip is clean, lightly buff the tip end in the same manner. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil and dry it with compressed air.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully insert reamer J 21089 in the injector body (Fig. 29). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.



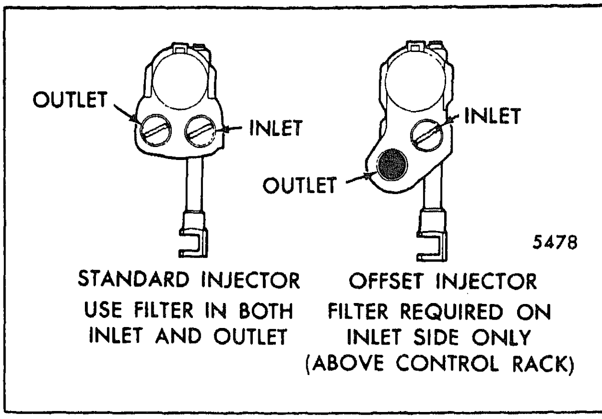


Fig. 34 - Location of Filter In Injector Body

Carefully insert carbon remover tool J 9418-1 in th injector nut. Turn it in a clockwise direction to remov the carbon deposits on the flat spray tip seat as show in Fig. 30. Remove the carbon deposits from the lowe end of the injector nut with carbon remover J 9418- (Fig. 30) in the same manner. Use care to preven removing any metal or setting up burrs on the spra tip seat.

Wash the injector nut in clean fuel oil and dry it wit compressed air. Carbon deposits on the spray ti seating surfaces of the injector nut will result in poo sealing and consequent fuel leakage around the spra tip.

When handling the injector plunger, do not touch th finished plunger surfaces with your fingers. Wash th plunger and bushing with clean fuel oil and dry ther with compressed air. Be sure the high pressure blee hole in the side of the bushing is not plugged. If th hole is plugged, fuel leakage will occur at the uppe end of the bushing where it will drain out of th injector body vent and rack holes, during engin operation, causing a serious oil dilution problem. *Kee the plunger and bushing together as they are mate parts.*

After washing, submerge the parts in a clea receptable containing clean fuel oil. *Keep the parts c each injector assembly together.*

Inspect Injector Parts

Inspect the teeth on the control rack and the contro rack gear for excessive wear or damage. Also check fo excessive wear in the bore of the gear and inspect th

ll automatically stop the flow of fuel
kes.

ıel stops flowing into the vial, pull the
no-fuel position.

nparator off and reset the counter.

reading on the vial and refer to Fig. 19
the injector fuel output falls within its
. If the quantity of fuel in the vial does
the specified limits, refer to *Trouble*
t 6 and *Shop Notes* in Section 2.0 for
remedy.

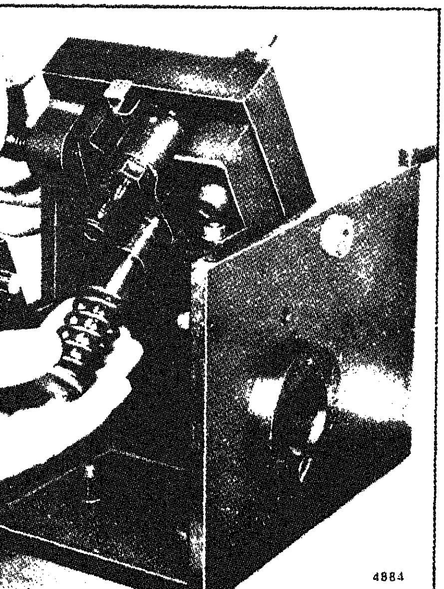
R J 22410

fuel output, operate the injector in the
. 21) as follows:

e the cam shift index wheel and fuel
n their respective positions. Turn on
el oil heater switch and preheat the
5 ° to 105 °F.

roper injector adaptor between the tie
ge it with the fuel block locating pin.
adaptor forward and up against the
.

injector seat J 22410-226 into the
t (cradle handle in vertical position).



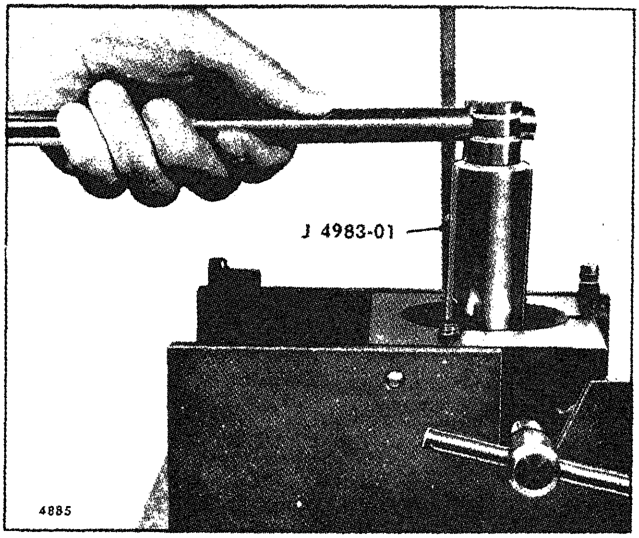


Fig. 25 - Removing Injector Nut

Clamp the injector into position by operating the air valve.

> **NOTE:** Make sure the counter (Fig. 22) on the calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

3. Pull the injector racks out to the no-fuel position.

4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

> **NOTE:** The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

5. After the calibrator has started, set the injector rack into the full-fuel position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

6. After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.

7. Shut the calibrator off (the calibrator will stop in

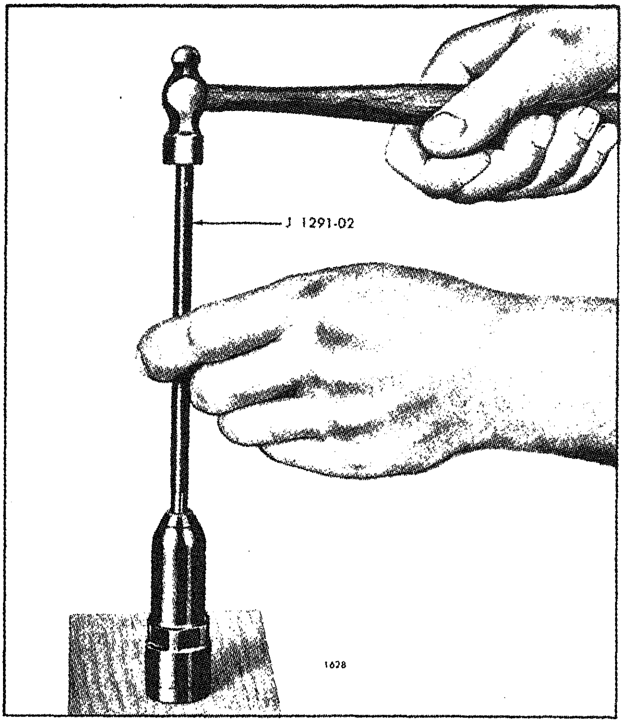


Fig. 26 - Removing Spray Tip from Injector Nut

the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to *Trouble Shooting Chart* 6 and *Shop Notes* in section 2.0 for the cause and remedy.

NOTE: Refer to Section 2.0 for different factors that may affect the injector calibrator output reading.

The comparator or the calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

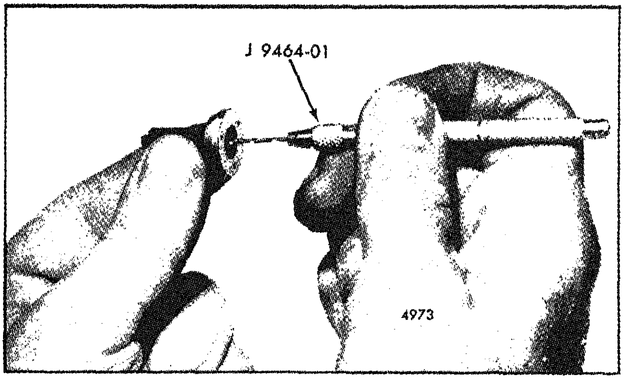


Fig. 27 - Cleaning Injector Spray Tip

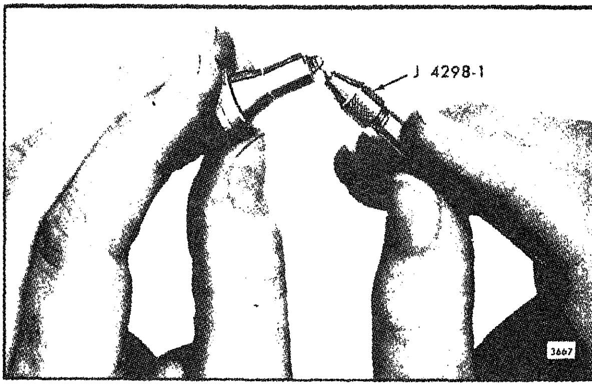


Fig. 28 - Cleaning Spray Tip Orifices

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the comparator or the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

Disassemble Injector

If required, disassemble an injector as follows:

1. Support the injector upright in injector holding fixture J 22396 (Fig. 23) and remove the filter caps, gaskets and filters.

NOTE: Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. *In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 34).*

2. Compress the follower spring as shown in Fig. 1

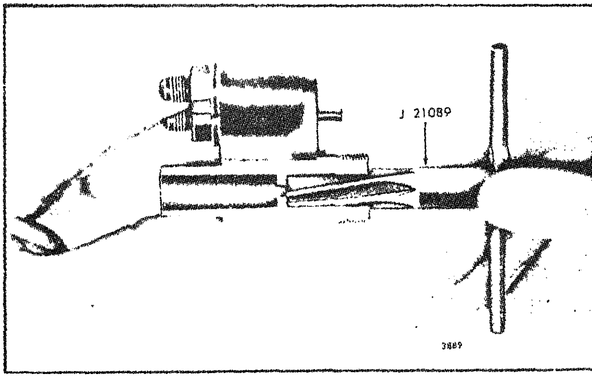
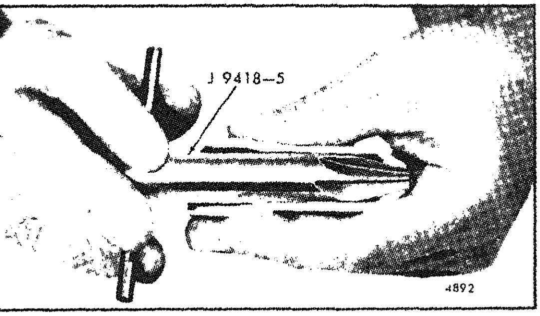


Fig. 29 - Cleaning Injector Body Ring



g. 30 · Cleaning Injector Nut Spray Tip Seat

raise the spring above the stop pin with a screw and withdraw the pin. Allow the spring to rise ally.

er to Fig. 24 and remove the plunger follower, er and spring as an assembly.

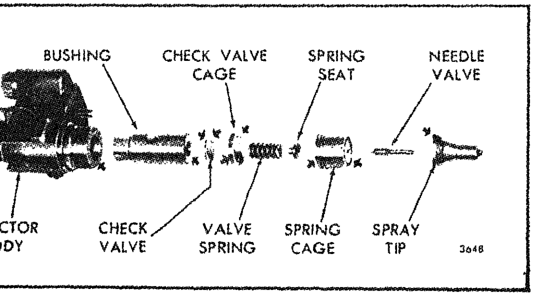
ert the fixture and, using socket J 4983-01, loosen t on the injector body (Fig. 25).

the injector nut straight up, being careful not to ge the spray tip and valve parts. Remove the tip and valve parts from the bushing and place n a clean receptacle until ready for assembly.

an injector has been in use for some time, the tip, even though clean on the outside, may not hed readily from the nut with the fingers. In this support the nut on a wood block and drive the wn through the nut, using tool J-1291-02 as in Fig. 26.

fer to Fig. 36 and remove the spill deflector. ift the bushing straight out of the injector body.

nove the injector body from the holding fixture. the body upside down and catch the gear r and gear in your hand as they fall out of the



g. 31 · Sealing Surfaces which may Require Lapping

8. Withdraw the injector control rack from the injector body. Also remove the seal ring from the body.

Clean Injector Parts

Since most injector difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. *Do not use waste or rags for cleaning purposes.* Clean out all of the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation. Methyl Ethyl Ketone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 9464-01 (Fig. 27).

> **CAUTION:** Care must be exercised when inserting the carbon remover J 9464-01 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1 and the proper size spray tip cleaning wire. Use wire J 21460 to clean .0055 " diameter holes and wire J 21461 to clean .006 " diameter holes (Fig. 28).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16 " with stone J 8170. Allow the wire to extend 1/8 " from tool J 4298-1.

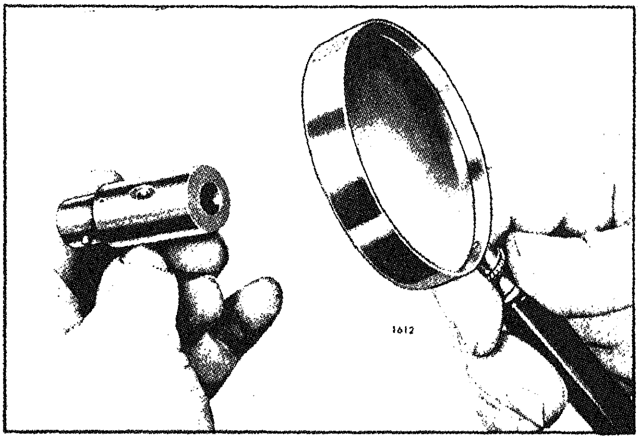


Fig. 32 · Examing Sealing Surface with a Magnifying Glass

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

CAUTION: Do not buff excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

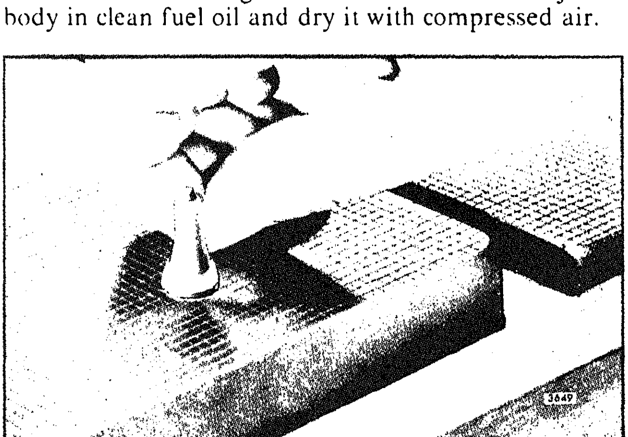
When the body of the spray tip is clean, lightly buff the tip end in the same manner. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil and dry it with compressed air.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully insert reamer J 21089 in the injector body (Fig. 29). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

Carefully insert a .375 " diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.



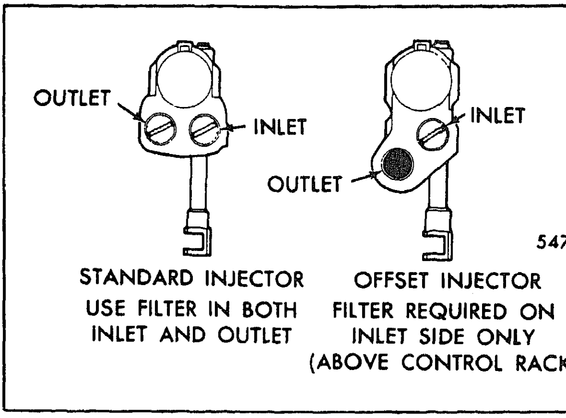


Fig. 34 - Location of Filter In Injector Body

Carefully insert carbon remover tool J 9418-1 i[n] injector nut. Turn it in a clockwise direction to re[move] the carbon deposits on the flat spray tip seat as s[hown] in Fig. 30. Remove the carbon deposits from the [l] end of the injector nut with carbon remover J 9[4] (Fig. 30) in the same manner. Use care to pr[event] removing any metal or setting up burrs on the s[pray] tip seat.

Wash the injector nut in clean fuel oil and dry it compressed air. Carbon deposits on the spray seating surfaces of the injector nut will result in sealing and consequent fuel leakage around the s[pray] tip.

When handling the injector plunger, do not touc[h] finished plunger surfaces with your fingers. Was[h] plunger and bushing with clean fuel oil and dry with compressed air. Be sure the high pressure b[ypass] hole in the side of the bushing is not plugged. If hole is plugged, fuel leakage will occur at the u[pper] end of the bushing where it will drain out of injector body vent and rack holes, during en[gine] operation, causing a serious oil dilution problem. *the plunger and bushing together as they are m[ated] parts.*

After washing, submerge the parts in a c[lean] receptable containing clean fuel oil. *Keep the pa[rts of] each injector assembly together.*

Inspect Injector Parts

Inspect the teeth on the control rack and the co[ntrol] rack gear for excessive wear or damage. Also chec[k for] excessive wear in the bore of the gear and inspec[t]

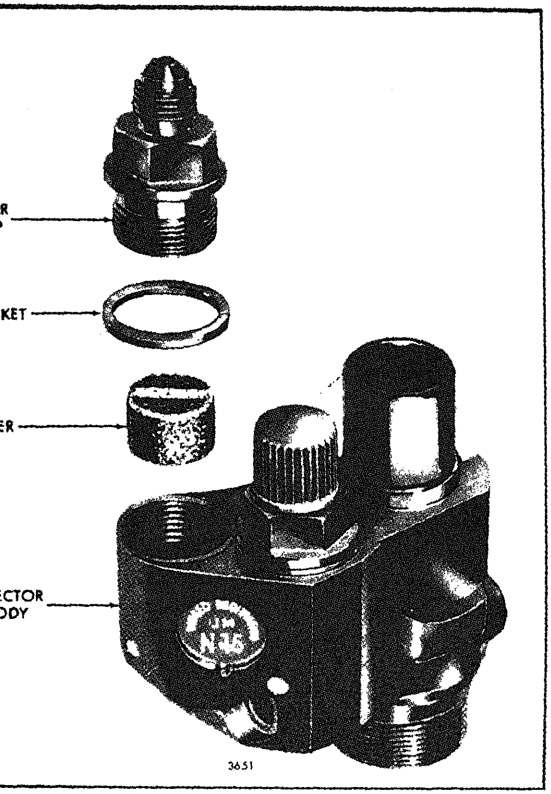


Fig. 35 · Details of Injector Filters and Caps and Their Relative Location

t both ends of the spill deflector for sharp edges rs which could create burrs on the injector body ector nut and cause particles of metal to be uced into the spray tip and valve parts. Remove with a 500 grit stone.

t the follower spring for visual defects. Then the spring with spring tester J 9666 and an te torque wrench.

urrent injector follower spring (.142 " diameter has a free length of approximately 1.504 " and be replaced when a load of less than 70 lbs. will ess it to 1.028 ".

ecommended that at the time of overhaul, all rs in an engine be converted to the current (.142 " diameter wire) which will provide ed cam roller to shaft follow. However, in the that one or two injectors are changed, the ing injectors need not be reworked to rate the current spring.

he seal ring area on the injector body for burrs tches. Also check the surface which contacts the bushing for scratches, scuff marks or other e. If necessary, lap this surface. A faulty sealing

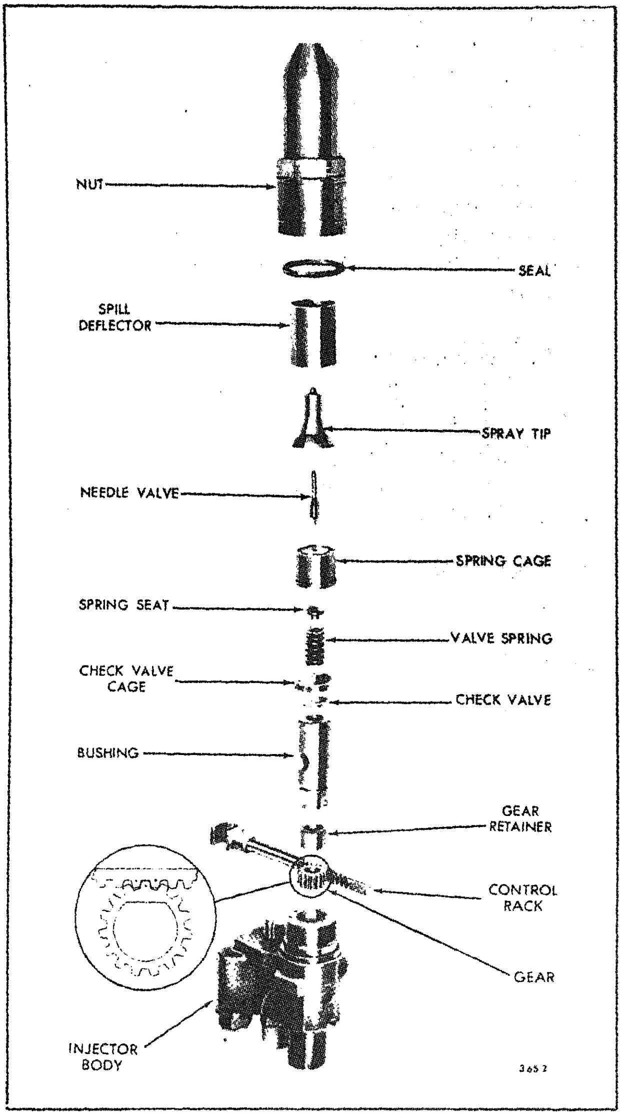


Fig. 36 · Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

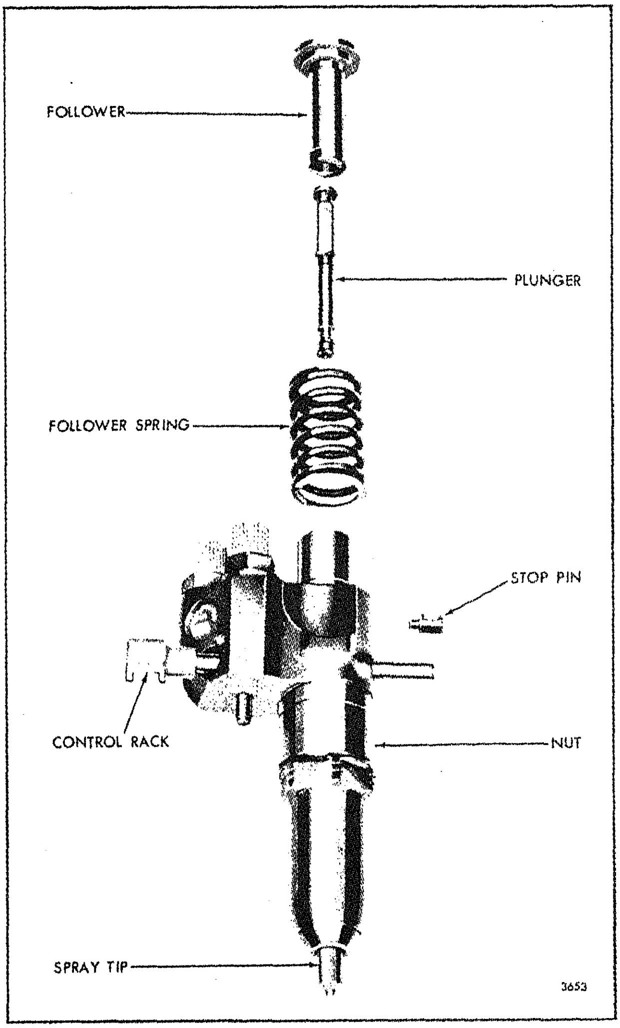
Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Injector Bushing Inspectalite J 21471 can be used to check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and

check for free movement. *Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts.* Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion or brinelling. Reseat the surface or replace the nut or tip if it is severely damaged.

The injector valve spring plays an important part in



Part Name	Minimum Thickness
Tip, Spray (Shoulder)	.199
Cage, Check Valve	.165-.163
Valve, Check	.022
Cage, Valve Spring	.602

MINIMUM THICKNESS (Used Parts)

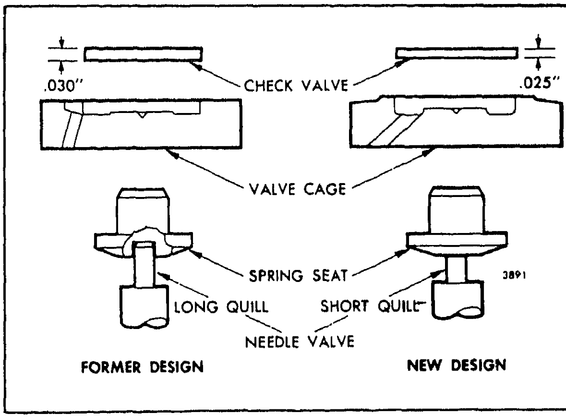
establishing the valve opening pressure of the inje assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the injector p indicated by arrows in Fig. 31. Examine the sea surfaces with a magnifying glass as shown in Fig. for even the slightest imperfections will prevent injector from operating properly. Check for bu nicks, erosion, cracks, chipping and excessive w Also check for enlarged orifices in the spray Replace damaged or excessively worn parts. Check minimum thickness of the lapped parts as noted in chart.

Examine the seating area of the needle valve for w or damage. Also examine the needle quill and contact point with the valve spring seat. Repl damaged or excessively worn parts.

Examine the needle valve seat area in the spray tip foreign material. The smallest particle of s material can prevent the needle valve from seat properly. Polish the seat area with polishing s J 22964. Coat only the tapered end of the stick w polishing compound J 23038 and insert it directly i the center of the spray tip until it bottoms. Rotate stick 6 to 12 times, applying a light pressure with thumb and forefinger.

CAUTION: Be sure that no compound is



accidentally placed on the lapped surfaces located higher up in the spray tip. The slightest lapping action on these surfaces can alter the near-perfect fit between the needle valve and tip.

Before reinstalling used injector parts, lap all of the sealing surfaces indicated by the arrows in Fig. 31. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

Lapping Injector Parts

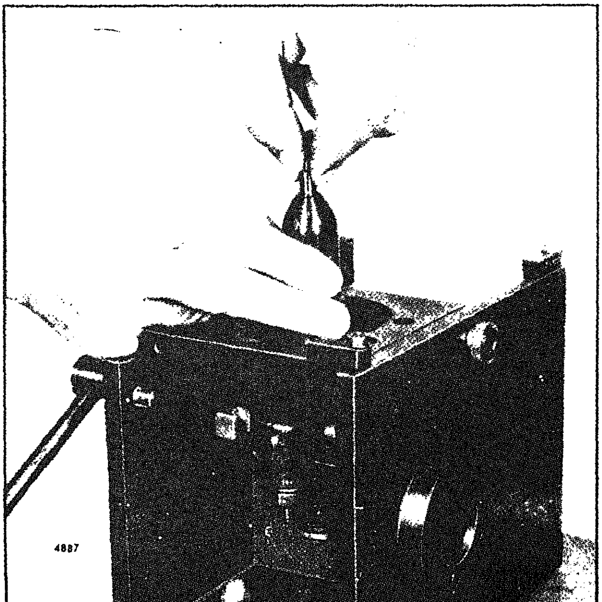
Lap the sealing surfaces indicated in Fig. 31 and the chart as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.

3 Place the part to be lapped flat on the block as shown in Fig. 33 and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.

4. After each four or five passes, clean the lapping



powder from the part by drawing it across a piece of tissue placed on a flat surface and inspec part. *Do not lap excessively* (refer to the char minimum thickness).

5. When the part is flat, wash it in cleaning so and dry it with compressed air.

6. Place the dry part on the second block. applying lapping powder, move the part lightly a the block in a figure eight motion several times to it a smooth finish. *Do not lap excessively.* Again the part in cleaning solvent and dry it with compr air.

7. Place the dry part on the third block. Do no lapping powder on this block. Keep the part flat move it across the block several times, using the f eight motion. Lapping the dry part in this ma gives it the "mirror" finish required for pe sealing.

8. Wash all of the lapped parts in clean fuel oil dry them with compressed air.

Assemble Injector

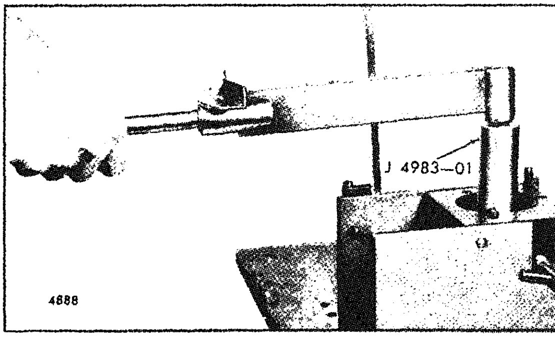
Use an extremely clean bench to work on and to the parts when assembling an injector. Also be su of the injector parts, both new and used, are clean

Study Figs. 34 through 37 for the proper rel position of the injector parts, then proceed as follo

ASSEMBLE INJECTOR FILTERS

Always use new filters and gaskets when reassem an injector.

1. Insert a new filter, dimple end down, slotted en



in each of the fuel cavities in the top of the injector body (Fig. 35).

> **NOTE:** Install a new filter in the inlet side (located over the injector rack) in a fuel injector with an offset body. No filter is required in the outlet side of the offset body injector (Fig. 34).

2. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65-75 lb-ft torque with a 9/16 " deep socket (Fig. 23).

3. Purge the filters after installation by directing compressed air or fuel through the filter caps.

4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

ASSEMBLE RACK AND GEAR

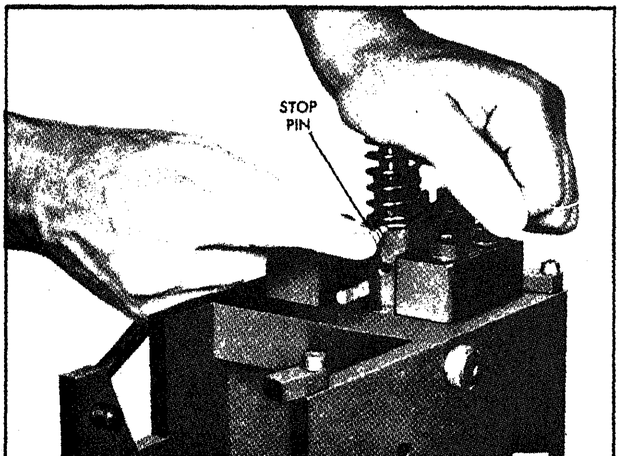
Refer to Fig. 36 and note the drill spot marks on the control rack and gear. Then proceed as follows:

1. Hold the injector body. bottom end up, and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 36).

3. Place the gear retainer on top of the gear.

4. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.



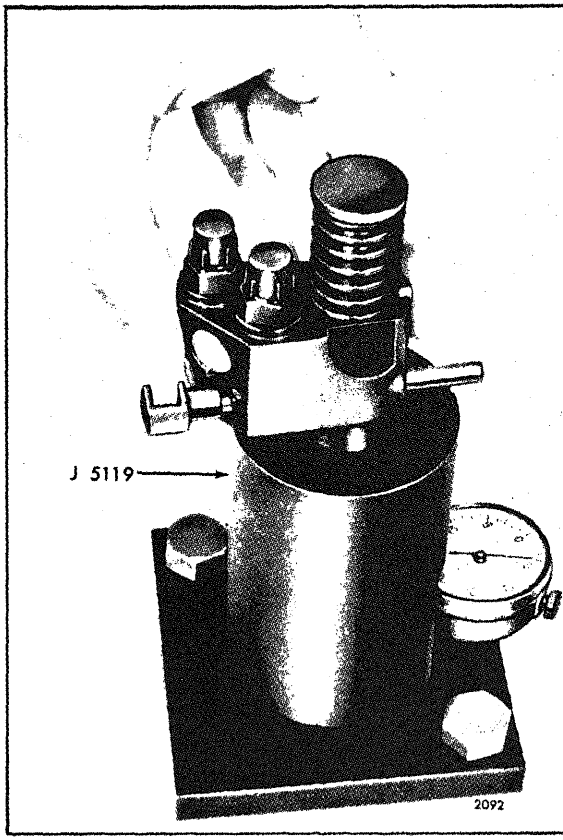


Fig. 42 - Checking Injector Spray Tip Concentricity

ASSEMBLE SPRAY TIP, SPRING CAGE AND CHECK VALVE ASSEMBLIES

Refer to Fig. 36 and assemble the parts as follows:

1. Support the injector body, bottom end up, injector holding fixture J 22396.

2. Place a new seal ring on the shoulder of the bo Then place the spill deflector over the barrel of bushing.

3. Place the check valve (without the .010 " h centrally on the top of the bushing. Then place check valve cage over the check valve and against bushing.

> **CAUTION:** The former and new check valve and check valve cage are not separately inter-changeable in a former injector (Fig. 38).

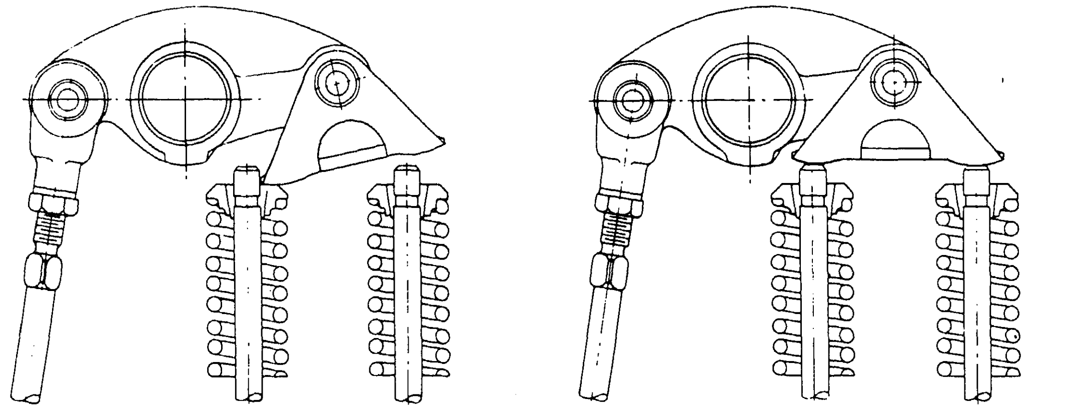


Fig. 43 · Relationship Between Exhaust Valve Bridge and Valve Stems

a former injector if a new design spray tip assembly is used.

5. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

CAUTION: When installing a new spray tip assembly in a former injector, a new valve spring seat must also be installed. The current needle valve has a shorter quill.

6. Insert the needle valve, tapered end down, inside of the spray tip (Fig. 2). Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

7. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 39). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

8. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 lb-ft torque (Fig. 40).

NOTE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

ASSEMBLE PLUNGER AND FOLLOWER

1. Refer to Fig. 37 and slide the head of the p into the follower.

2. Invert the injector in the assembly fixture (fil end up) and push the rack all the way in. Ther the follower spring on the injector body.

3. Refer to Fig. 41 and place the stop pin injector body so that the follower spring rests narrow flange of the stop pin. Then align the the follower with the stop pin hole in the i body. Next align the flat side of the plunger w slot in the follower. Then insert the free end plunger in the injector body. Press down follower and at the same time press the stop p position. When in place, the spring will hold th pin in position.

Check Spray Tip Concentricity

To assure correct alignment, check the concentri the spray tip as follows:

1. Place the injector in the concentricity gage J shown in Fig. 42 and adjust the dial indicator to

2. Rotate the injector 360° and note the total as indicated on the dial.

3. If the total run-out exceeds .008", remo injector from the gage. Loosen the injector nut, the spray tip and tighten the nut to 75-85 lb-ft Recheck the spray tip concentricity. If, after

attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under *Test Injector*.

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble and test the injector again.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286-9, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to Fig. 6 and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.

2. Slide the injector rack control lever over so that it registers with the injector rack.

3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20-25 lb-ft torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

> **NOTE:** Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0.

> **CAUTION:** On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridge (Fig. 43) before, during and after tightening the rocker shaft bolts.

5. Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb-ft torque.

> **CAUTION:** Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

6. Perform a complete engine tune-up as outlined in Section 14. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.

FUEL INJECTOR TUBE

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring and upset into a flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22525 as follows:

1. Remove, disassemble and clean the cylinder head as outlined in Section 1.2.

2. Place the injector tube installer J 5286-4 in the injector tube. Insert the pilot J 5286-5 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. 1).

3. Tap on the end of the pilot to loosen the injector tube. Then lift the injector tube, installer and pilot from the cylinder head.

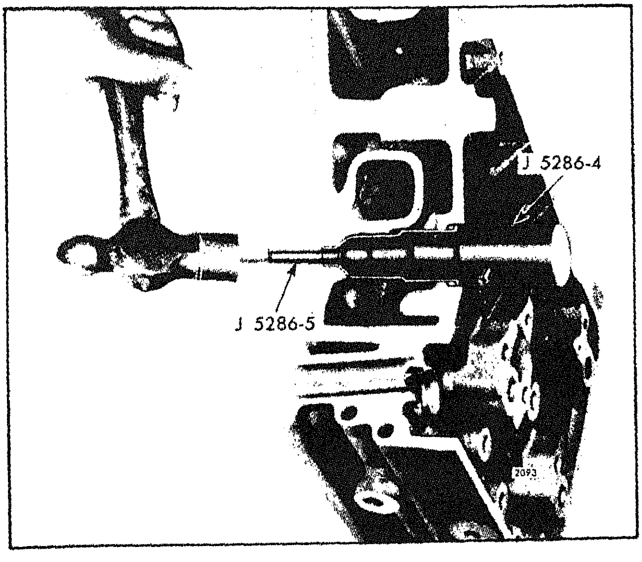


Fig. 1 - Removing Injector Tube

Install Injector Tube

Thoroughly clean the injector tube hole in the cyl head to remove dirt, burrs or foreign material may prevent the tube from seating at the lower e sealing at the upper end. Then install the tu follows:

1. Place a new injector tube seal ring in counterbore in the cylinder head.

2. Place the installer J 5286-4 in the injector Then insert the pilot J 5286-5 through the s opening of the injector tube and thread it int tapped end of the installer (Fig. 2).

3. Slip the injector tube into the injector bore drive it in place as shown in Fig. 2. Sealin accomplished between the head counterbore (i diameter) and outside diameter of the injector The tube flange is merely used to retain the seal ri

4. With the injector tube properly positioned in cylinder head, upset (flare) the lower end of injector tube as follows:

a. Turn the cylinder head bottom side up, remov pilot J 5286-5 and thread the upsetting

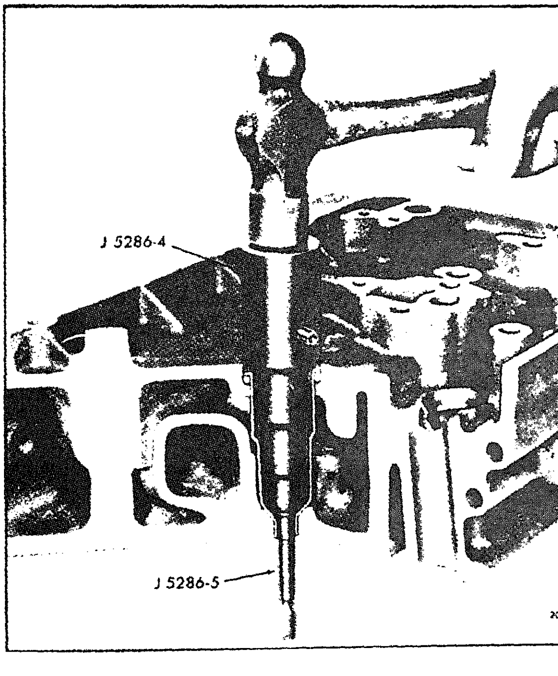


Fig. 2 - Installing Injector Tube

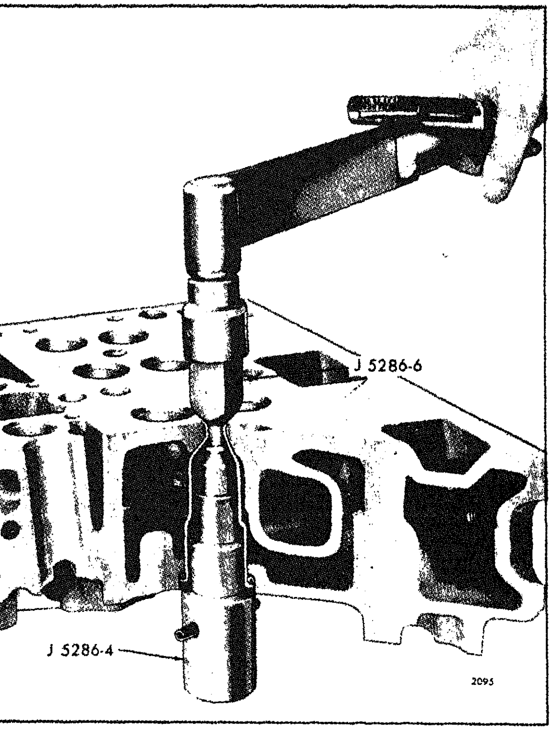


Fig. 3 · Upsetting Injector Tube

5286-6 into the tapped end of the installer 5286-4 (Fig. 3).

hen, using a socket and torque wrench, apply pproximately 30 lb-ft torque on the upsetting ie.

emove the installing tools and ream the injector ube as outlined below.

Injector Tube

an injector tube has been installed in a cylinder it must be finished in three operations: First, *reamed,* as shown in Fig. 4, to receive the or body nut and spray tip; second, *spot-faced* to e excess stock at the lower end of the injector and third, *hand reamed,* as shown in Fig. 5, to de a good seating surface for the bevel or the end of the injector nut. Reaming must be done lly and without undue force or speed so as to cutting through the thin wall of the injector

OTE: The reamer should be turned in a *ockwise direction* only, both when inserting d when withdrawing the reamer, because ovement in the opposite direction will dull the tting edges of the flutes.

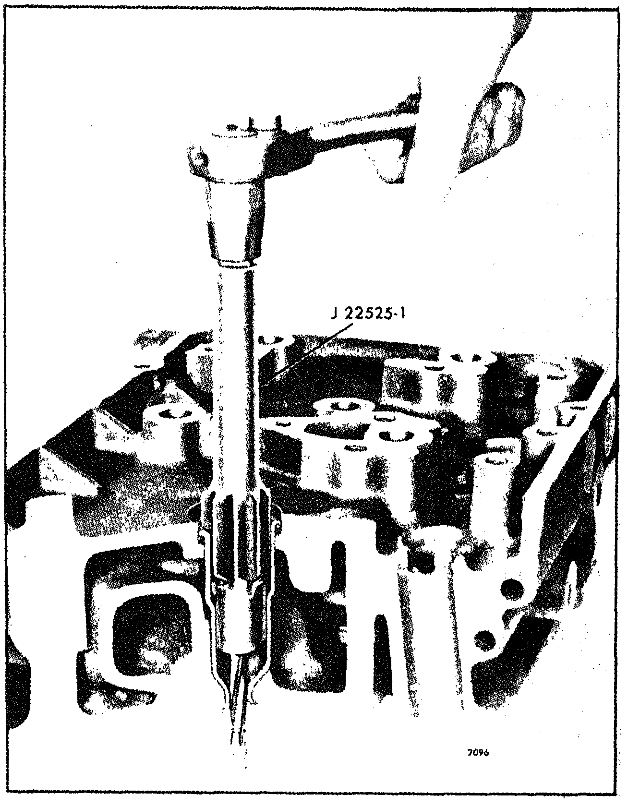


Fig. 4 · Reaming Injector Tube for Injector Body Nut and Spray Tip

1. Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:

a. Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22525-1 in the injector tube.

b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 4). Clean out all of the chips.

2. Remove excess stock:

a. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286-8 into the small hole of the injector tube.

b. Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to .005″ below the finished surface of the cylinder head.

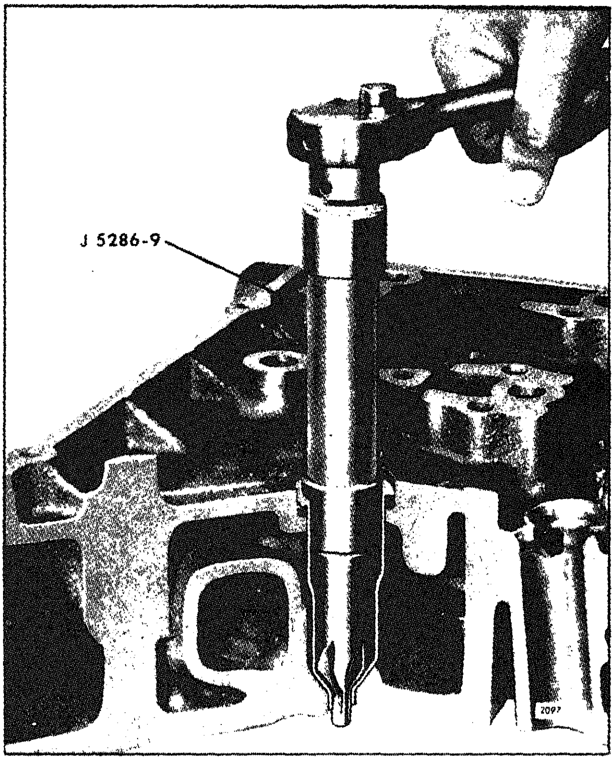


Fig. 5 - Reaming Injector Tube for Injector Nut

3. Ream the bevel seat in the injector tube:

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber. Therefore, to determine the amount of stock that must be reamed from the bevel seat of the tube, the injector assembly should be installed in the tube and the relationship between the numbered surface of the spray tip to the fire deck of the cylinder head noted (Fig. 6).

With the first reaming operation completed and the injector tube spot-faced, wash the interior of the

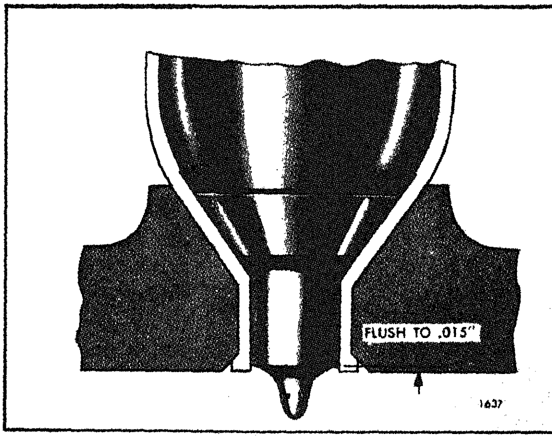


Fig. 6 - Checking Location of Injector Spray Tip Relative to Lower Surface of Cylinder Head

injector tube with trichloroethylene or clean fue and dry it with compressed air. Then perform second reaming operation as follows:

a. Place a few drops of cutting oil on the bevel of the tube. Carefully lower the reamer J 52 into the injector tube until it contacts the b seat.

b. Make a trial cut by turning the reamer stea without applying any downward force on reamer. Remove the reamer, blow out the c and look at the bevel seat to see what portio the seat has been cut.

c. Proceed carefully with the reaming operat withdrawing the reamer occasionally to obs the reaming progress.

d. Remove the chips from the injector tube using an injector as a gage, continue the rear operation until the shoulder of the spray ti within the limits specified in Fig. 6. Then v the interior of the injector tube with trichloro ylene or clean fuel oil and dry it with compre air.

FUEL PUMP

The positive displacement gear type fuel pump (Fig. 1) transfers the fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

On the In-line engine, the fuel pump is mounted on the governor weight housing and is driven through a drive coupling by the governor weight shaft.

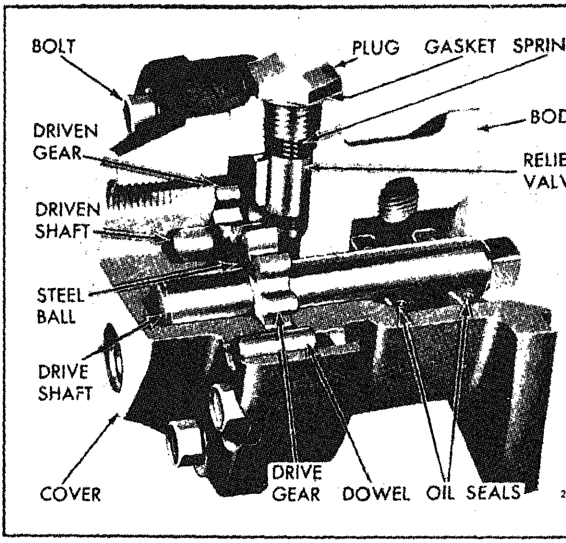


Fig. 1 - Typical Fuel Pump Assembly

The fuel pump cover and body are positioned by means of two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal-to-metal contact. A very thin coating of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The fuel pump body is recessed to provide running space for the pump gears (Fig. 2). Recesses are also provided at the inlet and outlet positions of the gears. The small hole "A" permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel re-enters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

compartment (Fig. 1). The oil seals are installed v the lips of the seals facing toward the flanged enc the pump body. A small hole "E" (Fig. 2) serves a vent passageway in the body, between the inner seal and the suction side of the pump, which preve building up any fuel oil pressure around the sh ahead of the inner seal. Two tapped holes in the un side of the pump body, between the oil seals, furnis means of attaching tubing for draining off leakage.

The drive and driven gears are a line-to-line to .001" press fit on their shafts. The drive gear provided with a gear retaining ball to locate the g on the shaft.

A spring-loaded relief valve incorporated in the pu body normally remains in the closed positi operating only when pressure on the outlet side (to fuel filter) reaches approximately 65 psi.

Operation

In operation, fuel enters the pump on the suction s and fills the space between the gear teeth which exposed at that instant. The gear teeth then carry fuel oil to the discharge side of the pump and, as gear teeth mesh in the center of the pump, the fuel is forced out into the outlet cavity. Since this i continuous cycle and fuel is continually being for into the outlet cavity, the fuel flows from the ou cavity into the fuel lines and through the engine

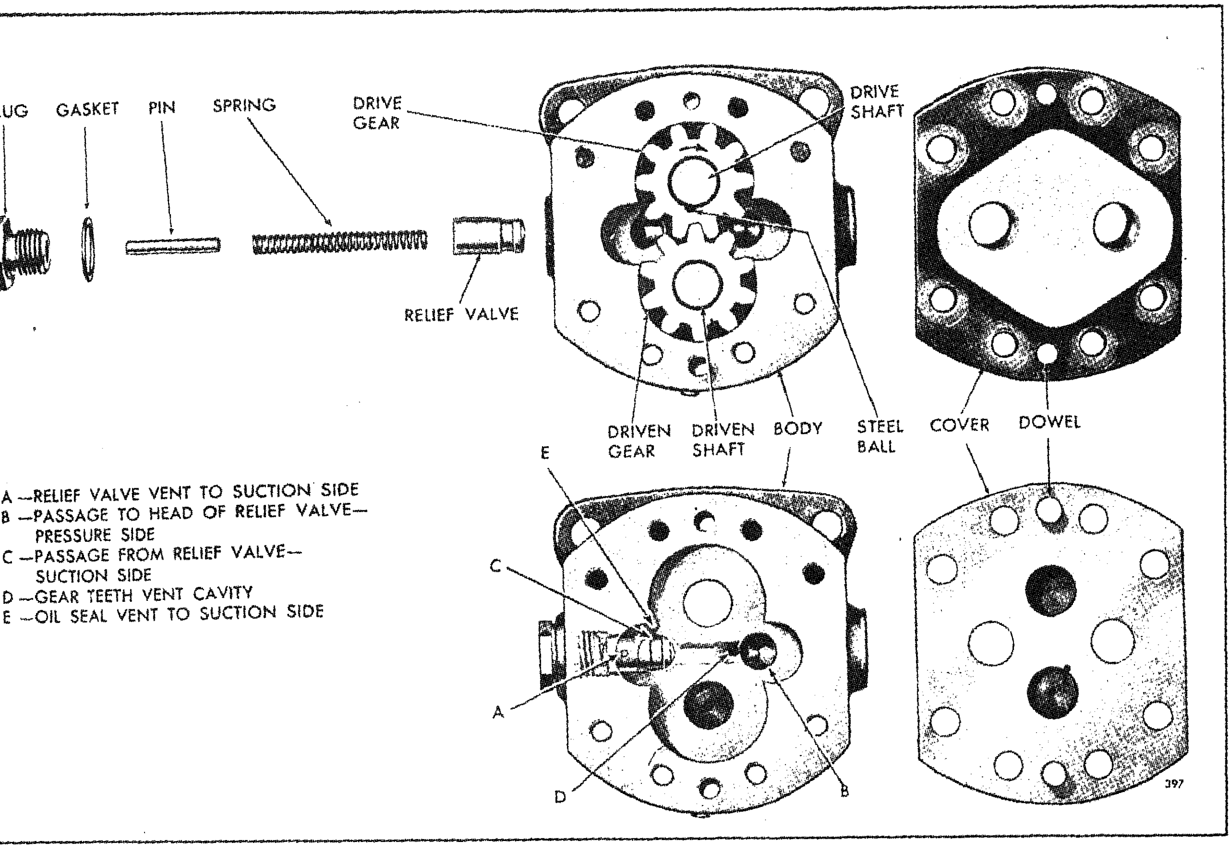


Fig. 2 - Fuel Pump Valving and Rotation (Right Hand Pump Shown)

mp to the inlet side when the discharge pressure es approximately 65 to 75 psi.

uel pump should maintain the fuel pressure at el inlet manifold as shown in Section 13.2.

kage exceeds one drop per minute, the oil seals be replaced.

ve Fuel Pump

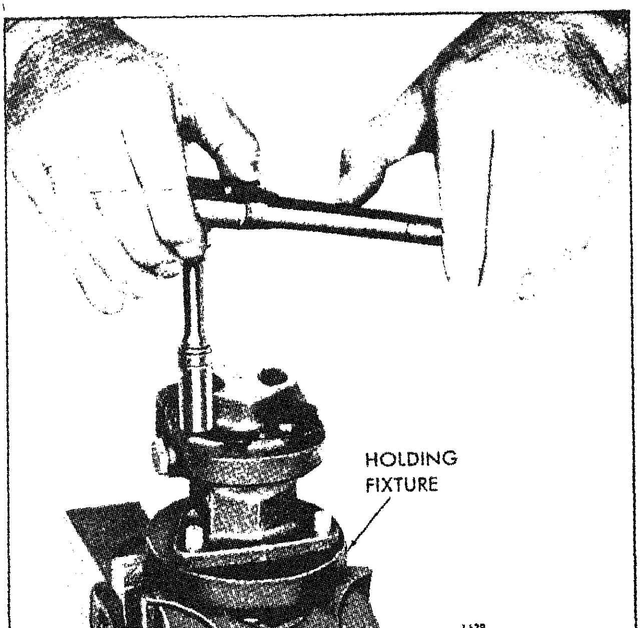
connect the fuel lines from the inlet and outlet ngs of the fuel pump.

connect the drain tube, if used, from the fuel

move the three pump attaching bolt and seal blies and withdraw the pump.

eck the drive coupling fork and, if broken or replace it with a new coupling.

Fig. 3, refer to Figs. 1 and 2 and disassemble the pump as follows:



1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.

2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.

3. Press the drive shaft just far enough to remove the steel locking ball. Then, invert the shaft and gear assembly and press the shaft from the gear. *Do not misplace the steel ball.* Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.

4. Remove the driven shaft and gear as an assembly from the pump body. Do not remove the gear from the shaft. The driven gear and shaft are serviced only as an assembly.

5. Remove the relief valve plug.

6. Remove the valve spring, pin and relief valve from the valve cavity in the pump body.

7. If the oil seals need replacing, remove them with tool J 1508-7, as shown in Fig. 4, by clamping the pump body in a bench vise and screwing the threaded end of the tool shaft into the outer oil seal (seal nearest to the bolting flange). Then tap the pilot end of the shaft with a hammer to remove the seal. Repeat this operation to remove the inner oil seal.

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals. The lips of the oil seals must fit snug around the pump shaft and must be free of nicks or cracks.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace with a new gear.

Inspect the drive and driven shafts for scoring or wear. Replace with new shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also check for wear at areas contacted by gears and shafts. Replace the cover or body if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the relief

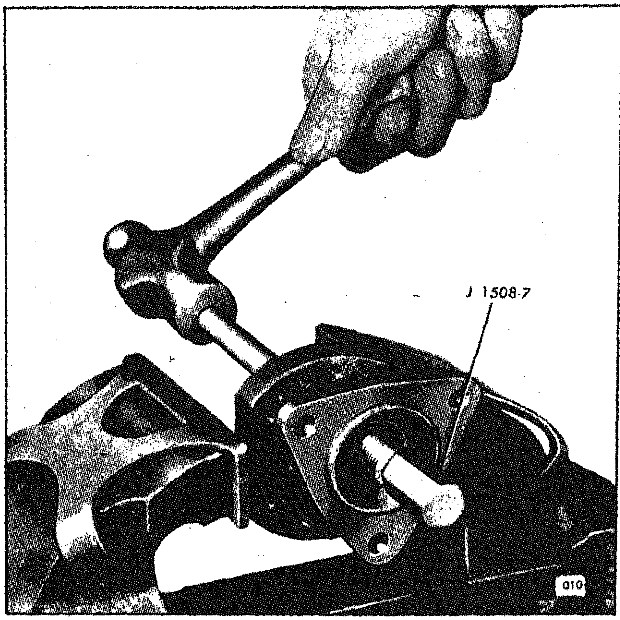


Fig. 4 - Removing Oil Seals

valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Assemble Fuel Pump

1. Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seals in the pump body as follows:

a. Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will face toward the shoulder on the tool.

b. With the pump body supported on wood blocks, insert the oil seal and tool in the pump body and drive the seal in until it bottoms in the counterbore (Fig. 6).

c. Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then, insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 7) until the shoulder of the adaptor contacts the pump body. Thus the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity

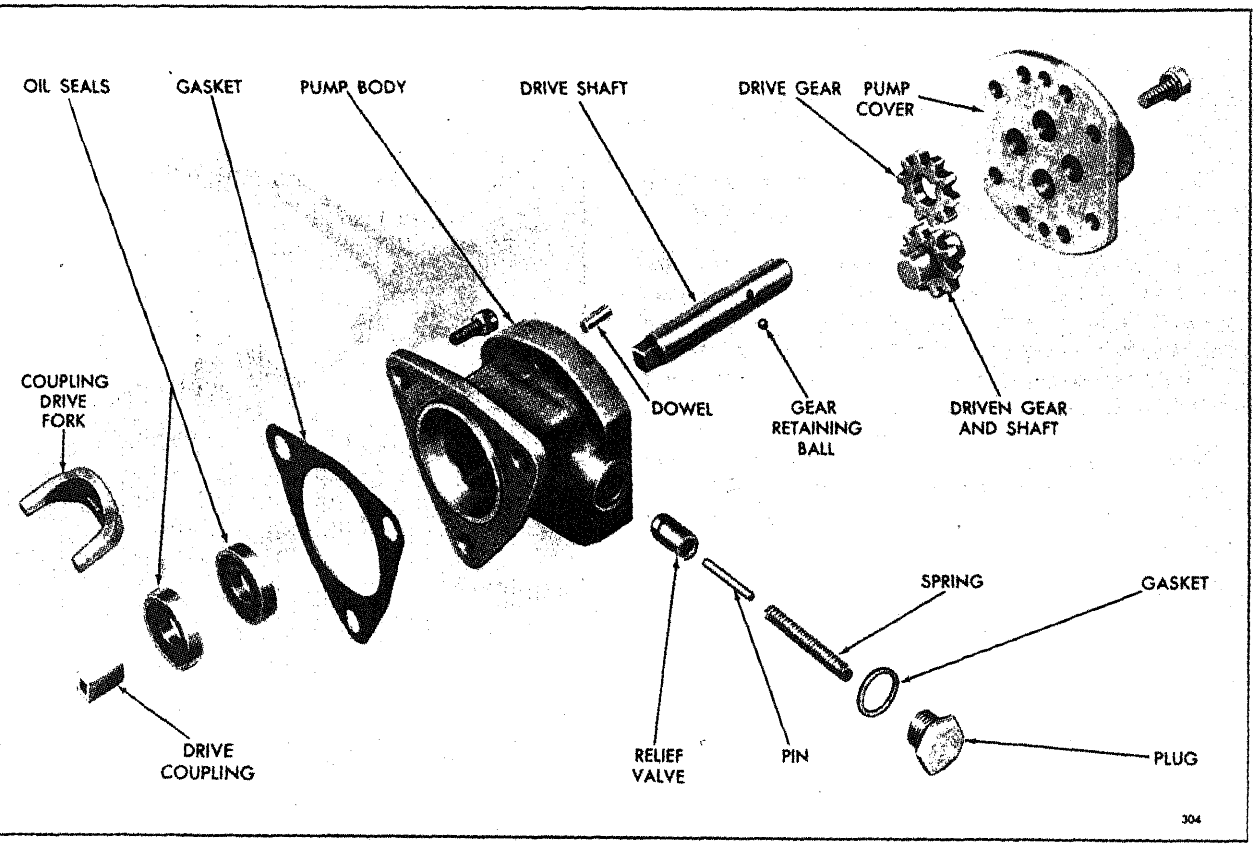


Fig. 5 · Fuel Pump Details and Relative Location of Parts (Right Hand Pump Shown)

:h the hollow end up. Insert the spring inside of the ve and the pin inside of the spring. With a new sket in place next to the head of the valve plug, ce the plug over the spring and thread it into the mp body. Tighten the plug.

Install the pump drive gear over the end of the ve shaft which is not squared (so the slot in the gear l face the plain end of the shaft). This operation is y important, otherwise fine score marks caused by essing the gear into position from the square end of shaft may cause rapid wear of the oil seals. Press gear beyond the gear retaining ball detent. Then, ce the ball in the detent and press the gear back til the end of the slot contacts the ball.

Lubricate the pump shaft and insert the square end the shaft into the opening at the gear side of the mp body and through the oil seals as shown in ;. 8.

Place the driven shaft and gear assembly in the mp body.

CAUTION: The driven gear must be centered on haft to give proper end clearance. Also, the ered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

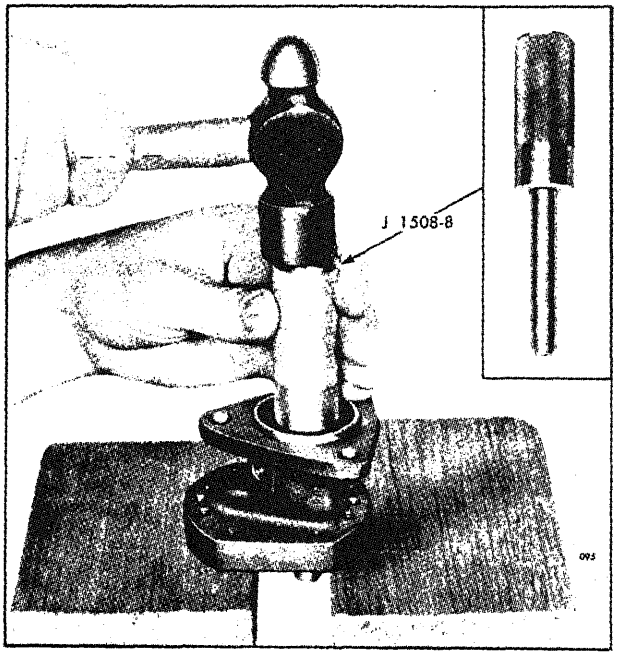


Fig. 6 · Installing Inner Oil Seal

6. Lubricate the gears and shafts with clean engine oil.

7. Apply a thin coating of quality sealant on the face of the pump cover outside of the gear pocket area. Then, place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

> **CAUTION:** The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

8. Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.

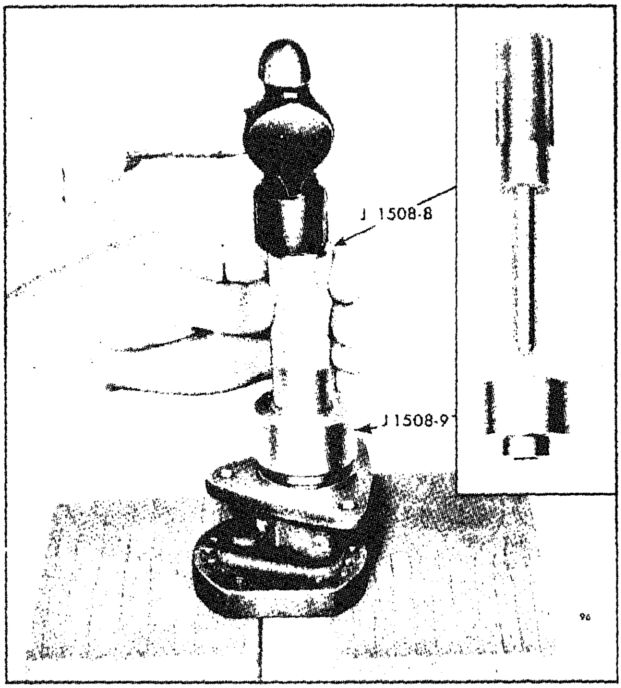


Fig. 7 - Installing Outer Oil Seal

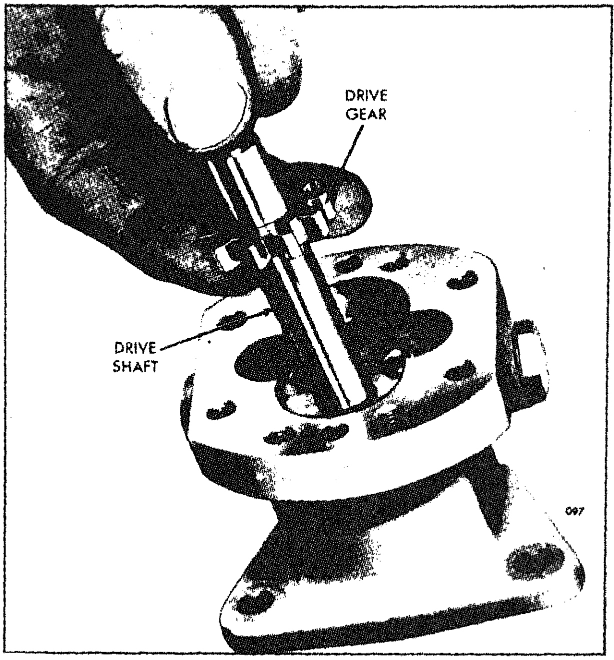


Fig. 8 - Inserting Fuel Pump Drive Shaft and Gear Assembly through Oil Seals

9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. When the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.

10. If the pump is not to be used immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

1. Affix a new gasket to the pump body and locate the pump drive coupling over the square end of the fuel pump drive shaft.

2. Install the fuel pump on the engine and secure it with three bolt and washer assemblies.

3. Connect the inlet and outlet fuel lines to the fuel pump.

FUEL PUMP DRIVE

The fuel pump on In-line engines is driven by the governor weight shaft by means of a drive coupling.

A drive adaptor attached to the balance shaft gear registers with a drive fork on the fuel pump shaft to provide a drive for the pump. Servicing of the fuel pump and drive on an In-Line engine is covered in Section 2,2

MECHANICAL GOVERNORS

Horsepower requirements on an engine may vary due to fluctuating loads; therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors. The following type of mechanical governor used:

1. Limiting Speed Mechanical Governor.

Engines requiring a minimum and maximum speed control, together with manually controlled intermediate speeds, are equipped with a limiting speed mechanical governor.

The governor has an identification plate located on the control housing, containing the governor assembly number, type, idle speed range and drive ratio. The maximum engine speed, not shown on the identification plate, is stamped on the option plate attached to the valve rocker cover.

Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine; however, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are present, check the engine as follows:

1. Make sure the speed changes are not the result of excessive load fluctuations.

2. Check the engine to be sure that all of the cylinders are firing properly (refer to Section 15.2). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in Section 2.1 or 2.1.1.

3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

1. If an injector rack sticks or moves too hard, it may be due to the injector hold-down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20-25 lb-ft torque.

2. An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in Section 2.1 or 2.1.1.

3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in Section 14.

4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no-fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in Section 14.

5. A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.

6. Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

LIMITING SPEED MECHANICAL GOVERNOR

IN-LINE ENGINE

The limiting speed mechanical governor (Fig. 1) performs the following functions:

1. Controls the engine idle speed.

2. Limits the maximum operating speed of the engine.

The mechanical engine governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor.

The governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

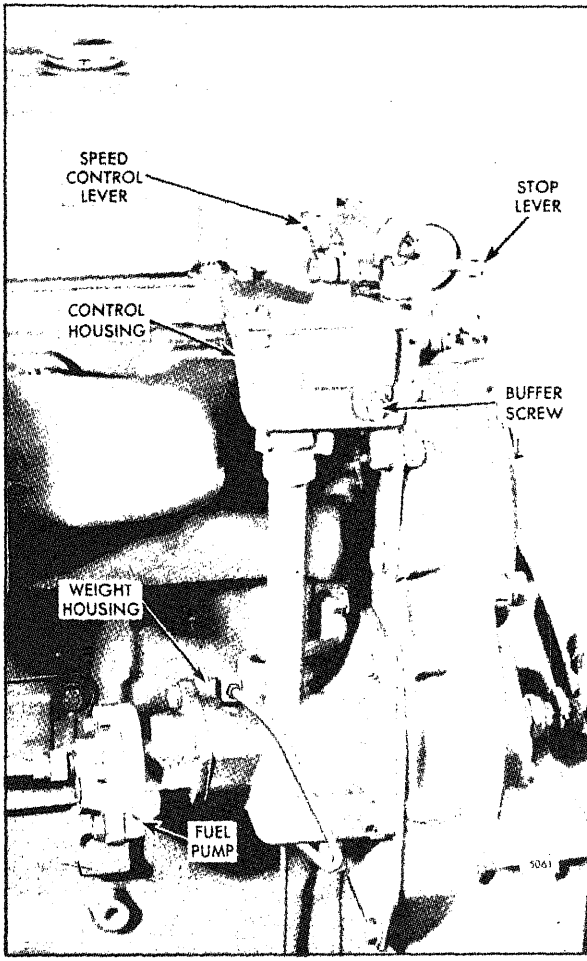


Fig. 1 - Governor Mounting

Operation

The governor holds the injector racks in the advanced fuel position for starting when the throttle control lever is in the idle position. Immediately after starting, the governor moves the injector racks to the position required for idling.

The centrifugal force of the revolving governor low and high speed weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever operates against the high and low speed springs through the spring cap, while the other end provides a moving fulcrum on which the differential lever pivots.

When the centrifugal force of the revolving governor weights balances out the tension on the high or low speed spring (depending on the speed range), the governor stabilizes the engine speed for a given setting of the speed control lever.

In the low speed range, the centrifugal force of the low and high speed weights together operate against the low speed spring. As the engine speed increases, the centrifugal force of the low and high speed weights together compresses the low speed spring until the low speed weights are against their stops, thus limiting their travel, at which time the low speed spring is fully compressed and the low speed spring cap is within .0015" of the high speed spring plunger.

Throughout the intermediate speed range the operator has complete control of the engine because the low speed gap is closed and the low speed weights are against their stops, and the high speed weights are no exerting enough force to overcome the high spee spring. As the speed continues to increase, th centrifugal force of the high speed weights increase until this force can overcome the high speed sprin and the governor again takes control of the engine limiting the maximum engine speed.

A fuel rod, connected to the differential lever and th injector control tube lever, provides a means for th governor to change the fuel settings of the injecto rack control levers.

The engine idle speed is determined by the forc exerted by the governor low speed spring. When th governor speed control lever is placed in the id position, the engine will operate at the speed where th force exerted by the governor low speed weights wi equal the force exerted by the governor low spee spring.

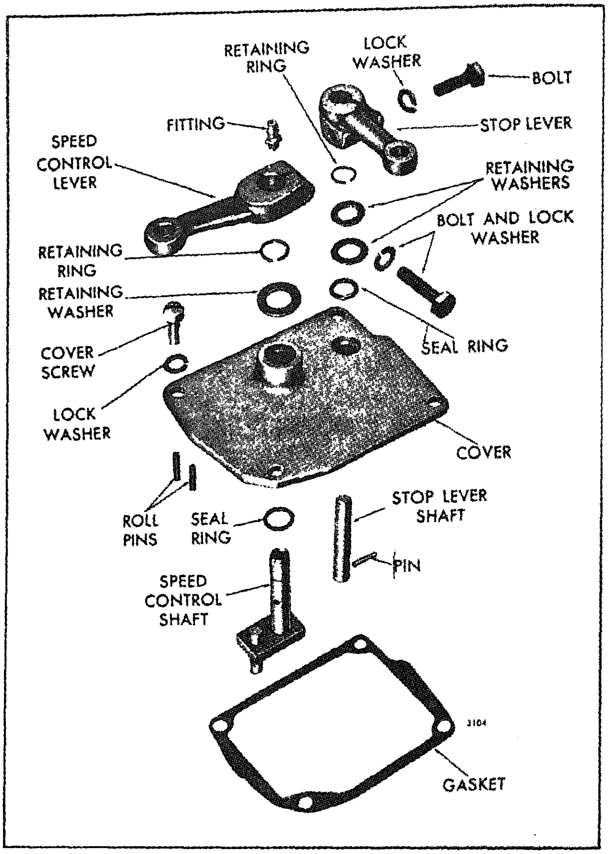


Fig. 2 - Governor Cover Details and Relative Location of Parts

Adjustment of the engine idle speed is accomplished by changing the force on the low speed spring by means of the idle speed adjusting screw. Refer to the tune-up section for idle speed adjustment.

The engine maximum no-load speed is determined by the force exerted by the high speed spring. When the throttle control lever is placed in the maximum speed position, the engine will operate at a speed where the force exerted by the governor high speed weights will equal the force exerted by the governor high speed spring.

Adjustment of the maximum no-load speed is accomplished by changing the tension on the high speed spring. Refer to the tune-up section for the maximum no-load speed adjustment.

Lubrication

The governor is lubricated

within the governor by the revolving weights. S oil drains from the governor through holes governor bearing retainer back to the engine train.

Remove Governor from Engine

Before removing the governor from the engin operation should be checked as outline Section 2.7. If the governor fails to control the properly after performing these checks, remov recondition it.

1. Disconnect the linkage to the governor c levers.

2. Remove the governor cover and gasket.

3. Detach the spring housing from the gov housing by removing the two bolts and lock wash

4. Loosen the high speed spring retainer lock nu spanner wrench J 5345-5 and remove the assembly.

5. Loosen the fuel rod cover hose clamps.

6. Clean and remove the rocker cover fron cylinder head.

7. Disconnect the fuel rod from the injector c tube lever. Remove the clip that holds the fuel r the differential lever and lift the fuel rod fror lever.

8. Detach the fuel pump by disconnecting the lines and removing the three bolts. Also, disco the lubricating oil line, if used.

9. Remove the five bolts from the governor w housing and the two bolts from the governor co housing.

10. Detach the governor and gasket from the engi

Disassemble Governor Cover

2. Remove the retaining ring and washer. Withdraw the speed control shaft from the cover.

3. Remove the seal ring from the cover.

NOTE: The double lever cover has the seal ring at the bottom of the cover.

4. Loosen the governor stop lever retaining bolt and lift the lever from the stop lever shaft.

5. Remove the retaining ring and washers and withdraw the stop lever shaft from the cover.

6. Remove the seal ring from the top of the cover.

Disassemble Governor Weight Housing

1. Remove the gear retaining nut from the shaft, then remove the gear, key and spacer from the shaft.

2. Remove the small screw holding the bearing retainer in place.

3. Turn the bearing support until the large opening is centered over the fork on the operating shaft.

4. Lift up on the weight shaft until there is enough clearance for a 5/16" socket wrench to be placed on

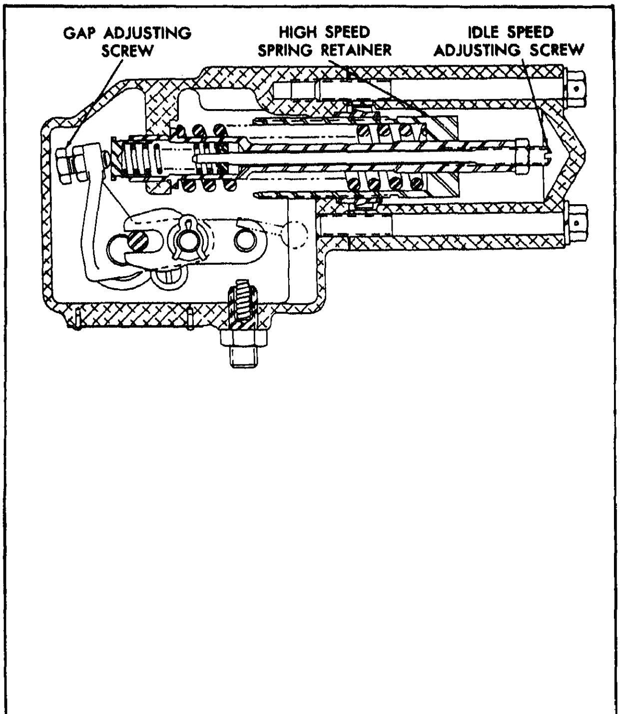


Fig. 3 Industrial

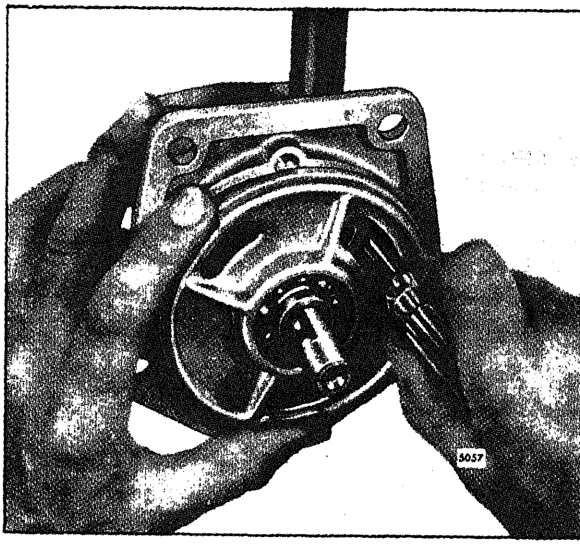


Fig. 4 - Removing Fork from Operating Shaft

the screws that hold the fork to the operating sha (Fig. 4). Then remove the two screws and washers.

5. Lift the shaft and weight assembly out of t governor weight housing.

6. Remove the screw and washers holding the beari in the control housing and lift the shaft assembly o of the housing.

7. Place a rod approximately 18" long through t control housing and knock the plug out of the botto of the weight housing.

8. Remove the snap ring and press the bearing fro the weight housing.

9. Remove the spring clip and washer from t governor operating shaft lever and remove t governor differential lever.

10. Press the bearing and operating shaft lever fro the operating shaft, if necessary.

11. If necessary, disassemble the control housing fro the weight housing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer from the weight shaft.

2. If necessary, remove the snap ring and press t bearing from the bearing retainer.

3. Remove the weight pin retainers from the govern weight pins, then drive the pins out of the carrier a

IMPORTANT: Punch mark the carrier at the retainer end of the weight pins so the pins may be placed in the proper position when reinstalling the weights in the carrier.

NOTE: Drive the pins out of the carrier from the weight pin retainer end.

. Slide the riser and bearing assembly from the shaft.)o not disassemble the bearing since the riser and earing are serviced only as an assembly.

ıspection

nmerse all of the governor parts in a suitable leaning fluid to loosen and remove all foreign ıaterial. Use a bristle brush and compressed air as ecessary to ensure cleanliness of all parts.

xamine the bearings for any indications of corrosion r pitting. Lubricate each bearing with light engine il; then, while holding the bearing inner race from ırning, revolve the outer race slowly by hand and heck for rough spots. Replace the bearings if rough r tight spots are detected.

he lower governor drive components have been evised to reduce the clearance between the riser and ıe weight shaft. With this change, additional ıbrication is provided to the governor by an oil line onnected between the oil gallery in the cylinder block nd the governor weight housing. When replacing the ser assembly, shaft and carrier assembly, or the omplete governor assembly, the new oil line must be ıstalled to provide adequate lubrication.

xamine the riser thrust bearing for excessive wear, at spots or corrosion. If any of these conditions exist, ıstall a new riser and bearing assembly. Examine the eight carrier pins for wear and replace them if ecessary.

ıspect the spring seats, plungers, adjusting screws, ck nuts and other parts of the control housing for efects that might affect governor operation.

ıspect the weight carrier, weights and retaining pins r wear. The current single-weight carrier replaces the rmer double-weight carrier.

ıspect the fuel pump drive end of the weight shaft. eplace the shaft if the end is worn or rounded.

lock nuts, and other parts of the control housing for defects that might affect the governor operation.

Assemble Governor Cover

1. Place a new seal ring in the counterbore of the cover (Fig. 2).

   NOTE: The single lever cover has the seal ring at the top of the cover. The double lever cover has the seal ring at the bottom of the cover.

2. Lubricate the speed control shaft with engine oil, then slide the shaft through the cover. Install the washer and retaining ring on the shaft.

3. Place the speed control lever over the shaft and secure it with the bolt and lock washer.

4. On double lever covers, lubricate the stop lever shaft with engine oil, then slide the shaft through the cover.

5. Place the seal ring in the counterbore of the shaft opening, then install the washers over the shaft. Lock the shaft in place with the retaining ring.

6. Place the stop lever on the shaft and secure it with the bolt and lock washer.

Assemble Control Housing

1. Install a 1/8" pipe plug in the tapped hole in the side of the control housing.

2. If necessary, assemble the control housing to the weight housing, using a good quality sealant between the tube and the housings.

3. Install the governor operating shaft lower bearing, numbered side out, in the weight housing. Install the snap ring to secure the bearing (Fig. 5).

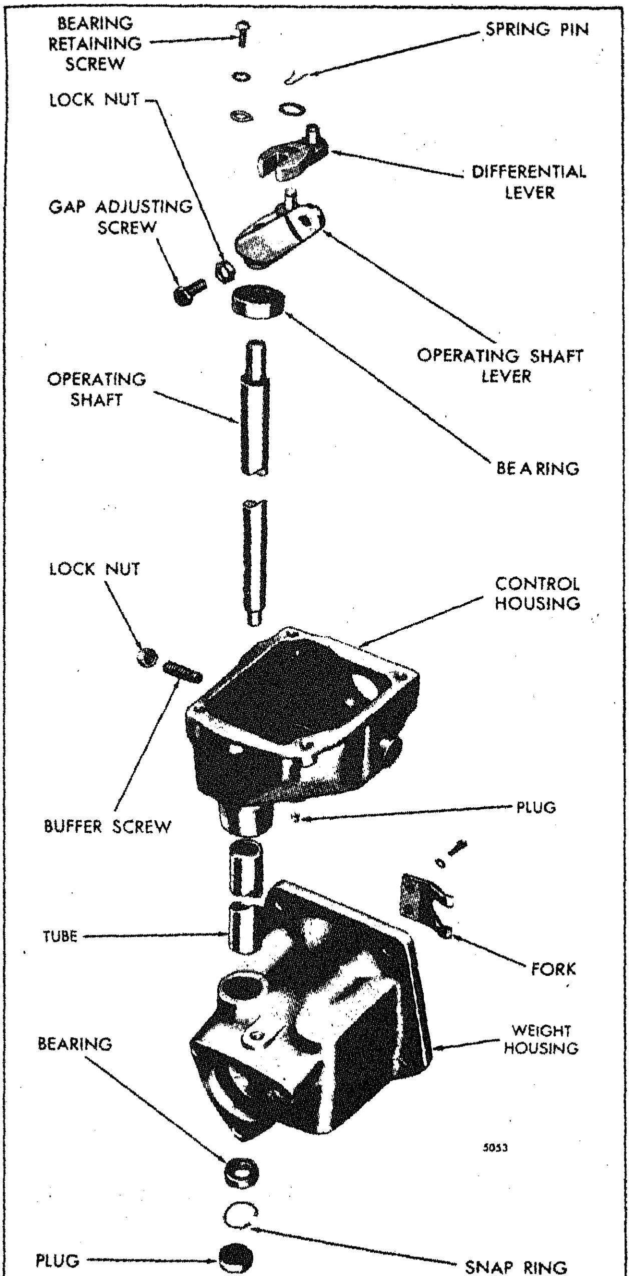
4. Apply a quality sealant around the edge of a new plug and tap it in place.

5. Start the governor operating shaft upper bearing over the upper end of the operating shaft. Support the lower end of the shaft on the bed of an arbor press. Use a sleeve and press down on the inner race of the bearing until it contacts the shoulder of the operating shaft.

7. Lubricate both bearings with engine lubricating oil. Insert the lever and operating shaft assembly in the control housing. Guide the lower end into the bearing.

8. Secure the upper operating shaft bearing with the round head retaining screw and washers.

9. Place the fork on the operating shaft with the two cam faces facing the fuel pump.



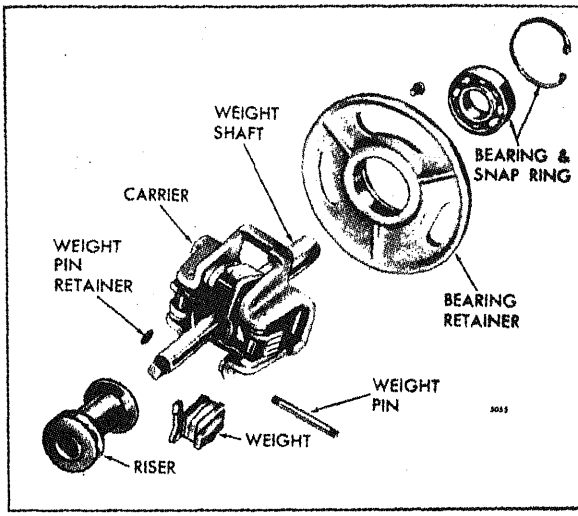


Fig. 6 - Governor Weight Details and Relative Location of Parts

10. Secure the fork to the operating shaft with t screws and lock washers.

11. Place the differential lever over the operating sha lever pin and secure it in place with a washer a spring pin.

Assemble Governor Weight and Shaft Assembly

1. If the carrier was removed from the weight sha press the carrier on the shaft so as to allow a cleara of .001" to .006" between the shaft shoulder and rear face of the carrier.

2. Press the governor weight shaft bearing into bearing retainer by pressing on the outer race of bearing (Fig. 6).

3. Install the snap ring in the retainer with the flat s of the ring facing the bearing.

4. Press the bearing retainer on the weight shaft u the bearing is against the shoulder on the shaft.

NOTE: To prevent any damage, press only on the inner race of the bearing.

5. Place the riser on the weight shaft.

6. Position the low speed weights, identified by

ll the high speed weights in the same way. The
eed weights are identified by the long cam arm
ee center laminations; the middle lamination is
thick and the outer ones are 1/8" thick.

TE: The weight pins must be reinstalled in
same positions from which they were
oved.

e the shaft and weight assembly into the weight
g with the riser bearing placed behind the fork.

n the bearing retainer until the large opening is
e fork on the operating shaft. Tighten the two
holding the fork to the operating shaft with a
socket wrench.

rn the bearing retainer until the counterbored
n the retainer and housing line up. Install the
to secure the bearing retainer to the weight
g.

ce the drive gear spacer on the shaft. Install the
the keyway and place the gear on the shaft.

ap the gear until the spacer is against the
g. Install the drive gear retaining nut and
n it to 125-135 lb-ft torque.

Governor

to Fig. 1 and install the governor on the engine
ows:

ach the fuel rod to the differential lever and
it in place with a washer and spring pin.

ch a new gasket to the governor weight housing.

rt the end of the fuel rod through the hose and
s and into the opening in the cylinder head and
n the governor weight housing against the
rear end plate; the teeth on the governor drive
ust mesh with the teeth on the camshaft gear or
e shaft gear.

all the three 12-point head bolts with copper
s in the governor weight housing next to the
er block. Install the two remaining bolts with
ashers and lock washers. Tighten the bolts to 35
rque.

and fittings to the weight housing and the cylinder block.

7. Align and tighten the hose clamps on the fuel rod covers.

8. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.

9. Assemble the industrial governor spring mechanism as follows:

a. Thread the spring retainer lock nut on the retainer.

b. Thread the idle speed adjusting screw on the governor spring plunger.

c. Place the high speed spring over the governor spring plunger.

d. Lubricate and install the spring plunger assembly in the spring retainer and secure it with a lock nut so that approximately 1/4" of the idle speed adjusting screw extends beyond the nut.

e. Lubricate and insert the spring seat, low speed spring and the spring cap in the open end of the spring plunger.

10. Thread the spring retainer and spring assembly into the governor housing and tighten the lock nut finger tight until an engine tune-up is performed.

11. Assemble the vehicle governor spring mechanism as follows:

a. Back off the lock nut at the outer end of the adjusting screw to within 1/16" of the slotted end of the screw.

b. Slip the shims, if used, and the high speed spring over the plunger. Position the retainer over the high speed spring and insert the adjusting screw into the plunger.

c. Position the seat and cap on the ends of the low speed spring and insert the assembly into the hollow end of the plunger.

d. Insert the spring and plunger assembly into the control housing and tighten the retainer nut with spanner wrench J 5895.

13. Use a new gasket when installing the governor cover and lever assembly. Be sure the speed control shaft pin engages the slot in the differential lever and the stop lever is in the correct position. Secure the cover with four screws and lock washers.

14. Install the return spring and spring clip (single lever cover only).

15. Add lubricant to the speed control shaft through the grease fitting on top of the shaft.

16. Connect the linkage to the governor control levers.

17. Install the fuel pump and fuel lines.

18. Perform an engine tune-up as outlined in Section 14.

SHOP NOTES-TROUBLE SHOOTING-SPECIFICATIONS-SERVICE TOOLS

SHOP NOTES

CHECKING INJECTOR TESTER J 9787

The injector tester J 9787 should be checked monthly to be sure that it is operating properly. The following check can be made very quickly using test block J 9787-49.

Fill the supply tank in the injector tester with clean injector test oil J 8130. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all of the air is out of the test block; then clamp the fuel outlet connector onto the test block. Break the connection at the gage and operate the pump handle until all of the air bubbles in the fuel system disappear. Tighten the connection at the gage. Operate the pump handle to pressurize the tester fuel system to 2400-2500 psi. Close the valve on the fuel supply line. After a slight initial drop in pressure, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector.

Occasionally dirt will get into the pump check valv the tester, resulting in internal pump valve leak and the inability to build up pressure in the tester system. Pump valve leakage must be corrected be an injector can be properly tested.

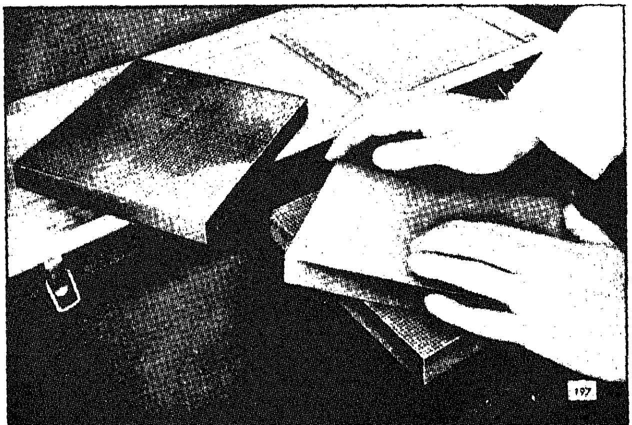
When the above occurs, loosen the fuel inlet conne clamp and operate the tester pump handle in attempt to purge the dirt from the pump check va A few quick strokes of the pump handle will usu correct a dirt condition. Otherwise, the pump ch valve must be removed, lapped and cleaned, replaced.

If an injector tester supply or gage line is damaged broken, install a new replacement line (available fr the tester manufacturer). Do not shorten the old li or the volume of test oil will be altered sufficiently give an inaccurate valve holding pressure test.

If it is suspected that the lines have been altered, by shortening or replacing with a longer line, ch the accuracy of the tester with a master injector which the pressure holding time is known. If pressure holding time does not agree with recorded for the master injector, replace the lines.

REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfa they should be refinished from time to time.



It is a good practice, where considerable lapping w is done, to devote some time each day to refinish the blocks. The quality of the finished work depend a great degree on the condition of the lapping surfa of the blocks.

To refinish the blocks, spread some 600 grit lapp powder of good quality on one of the blocks. P another block on top of this one and work the blo together as shown in Fig. 1. Alternate the blocks fr time to time. For example, assuming the blocks numbered 1, 2 and 3, work 1 and 2 together, the and 3, and finish by working 2 and 3 toget Continue this procedure until all of the blocks

ctory when the entire surface is a solid dark Bright or exceptionally dark spots indicate and additional lapping is required.

the surfaces have been refinished, remove the powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

INJECTOR TIMING

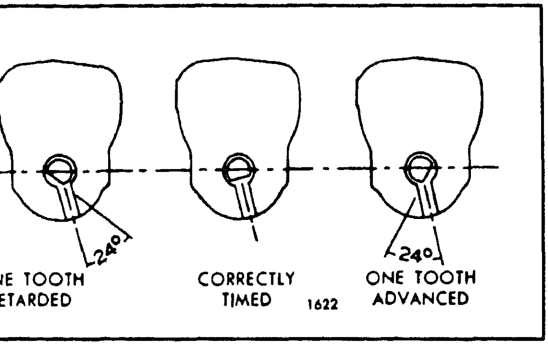


Fig. 2 · Injector Rack-to-Gear Timing

If it is suspected that a fuel injector is "out of time", the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (Fig. 2) and appears in the "advanced" or "retarded" position, the injector should be disassembled and the rack- to-gear timing corrected.

FUEL INJECTOR SPRAY TIPS

o a slight variation in the size of the small s in the end of each spray tip, the fuel output of ector may be varied by replacing the spray tip.

Flow gage J 21085 may be used to select a spray tip that will increase or decrease the fuel injector output for a particular injector after it has been rebuilt and tested on the comparator.

EFFECT OF PRE-IGNITION ON FUEL INJECTOR

nition is due to ignition of fuel or lubricating oil e combustion chamber before the normal on period. The piston compresses the burning e to excessive temperatures and pressures and ventually cause burning of the injector spray tip ad to failure of the injectors in other cylinders.

pre-ignition occurs, all of the injector assemblies should be removed and checked for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of pre-ignition to avoid a recurrence of the problem. Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

BLUING INJECTOR BODIES AND NUTS

ppearance of the injector body and nut of a injector can be enhanced with an oxide finish ed through a dipping process known as g". Pre-mixed compounds are available com-lly for preparing the necessary solutions. ed instructions are usually provided with the ercial compounds. An effective bluing solution e prepared in the service shop by mixing the ing materials:

of sodium hydroxide per gallon of water

3-1/2 lbs. of sodium nitrite per gallon of water

1 ounce of phosphoric acid per gallon of water

The procedure usually follows five (5) steps in sequence:

1. An alkaline solution bath (180 °-212 °F.) to preclean.

2. A hot or cold water rinse.

3. The bluing solution bath.

4. A cold water rinse.

5. An engine lubricating oil bath (180 °-212 °F.) to rust proof. The bluing tank should be a double walled, 1-1/2 " insulated type of No. 10 gage steel.

The temperature of the sodium hydroxide, sodium nitrite and phosphoric acid solution for bluing steel parts should be 295 ° to 305 °F. The boiling point of the solution is directly related to its concentration. Therefore, when the boiling point is too high, the solution is too concentrated and the volume of water is probably low. When this occurs, the boiling point can be reduced to 300 °F. by adding water. The parts should be placed in the solution for 15 to 30 minutes.

It is extremely important that the parts be free of oil before placing them in the bluing bath. Oil will produce a varied color part.

There are several important safety precautions to followed for preparing and using the solutio Protective clothing such as rubber gloves, rub aprons and protective glasses contribute to the saf of personnel carrying out the procedures. W preparing the solutions, *the compounds should be ad to the water* and not water added to the compour The dipping tanks should be properly vented and fumes exhausted to the outside atmosphere. Si temperatures of the caustic solutions exceed boiling point of water, any splashing encounte while adding make-up water can cause serious bu *Always add water slowly and with extreme care.* Wl the parts to be dipped are cold, caution should taken to avoid splashing that might occur when cold parts come in contact with the hot solutions. heavy wire-screen type basket, suitable for holding quantity of injector bodies, is recommended dipping the parts in the solutions.

INJECTOR COMPARATOR AND CALIBRATOR READINGS

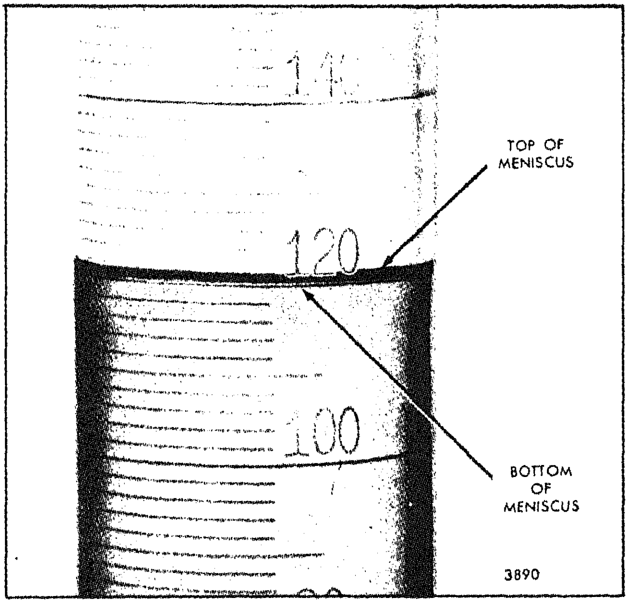


Fig. 3 - Checking Fuel Output

Several factors affect the injector comparator and calibrator output readings. The four major items are:

1. **Operator Errors:** If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. Refer to Fig. 3.

before the air is purged from the injector and lines, from an air leak on the vacuum side of the pump.

3. **Counter Improperly Set:** The counter is set at factory to divert the injector output at 1,000 strok

This should not be confused with counter overrun t will vary from 2 to 6 digits, depending upon inter friction. The fuel diversion is accomplished electrica and will occur at 1,000 strokes (if properly s although the counter may overrun several digits.

4. **Test Oil:** A special test oil is supplied with calibrator and the comparator and should always used. If regular diesel fuel oil (or any other liquid) used, variations are usually noted because of the aff of the oil on the solenoid valve and other parts.

The fuel oil introduced into the test oil when the f injector is placed in the comparator or calibrator fo calibration check contaminates the test oil. Therefo it is important that the comparator or calibrator ha the test oil and test oil filter changed every six mont or sooner if necessary.

In addition, other malfunctions such as a slipp drive belt, low level of fuel oil, a clogged filter defective fuel pump or leaking line connections co

FUEL INJECTOR PLUNGERS

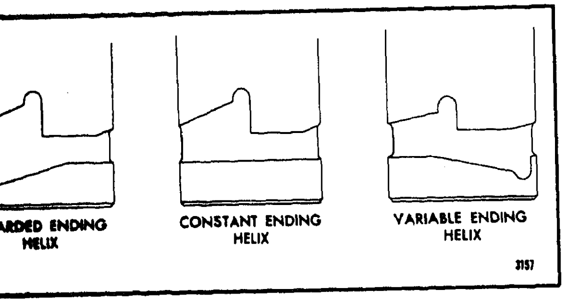


Fig. 4 - Types of Injector Plungers

e fuel output and the operating characteristics of an injector are, to a great extent, determined by the type of plunger used. Three types of plungers are illustrated in Fig. 4. The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retards or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled. If injectors with different type plungers (and spray tips) are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

REPLACING INJECTOR FOLLOWER SPRING

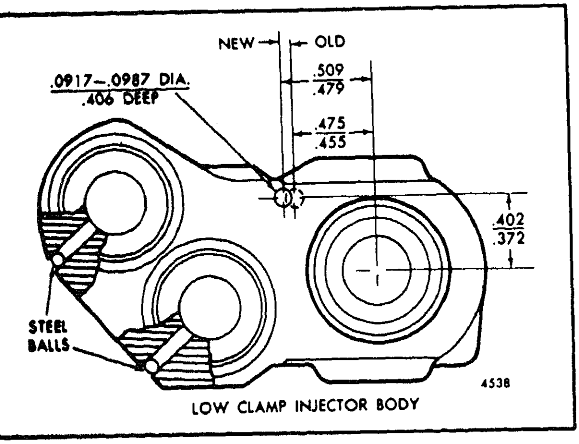


Fig. 5 - Relocating Timing Pin Hole in Injector Body

When replacing the injector follower spring (.120 " diameter wire) in a low clamp body injector built prior to June, 1965 with a new injector follower spring (.142 " diameter wire), it will be necessary to relocate the timing pin holes as illustrated in Fig. 5, or grind .022 " from the side of the injector timing gage shank, to permit continued use of the injector timing gage.

REFINISHING FACE OF INJECTOR FOLLOWER

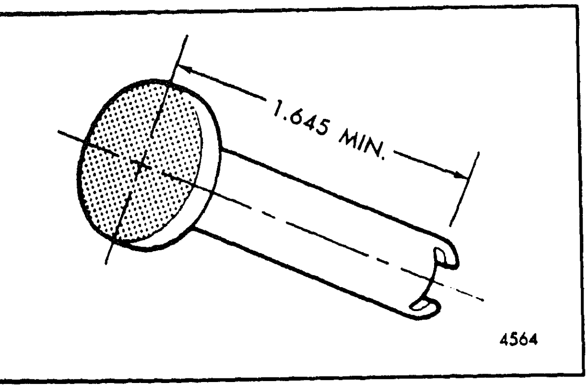


Fig. 6 - Injector Follower

When refinishing the face of an injector follower, it is extremely important that the distance between the injector face and the plunger slot is not less than the 1.645 " minimum shown in Fig. 6.

If the distance between the injector face and the plunger slot is less than 1.645 ", the height of the follower in relation to the injector body will be altered and proper injector timing cannot be realized.

> **NOTE:** To ensure a sufficiently hardened surface for rocker arm contact, do not remove more than .010 " of metal from the injector follower head.

LOCATING AIR LEAKS IN FUEL LINES

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return tube in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observation of the fuel filter contents after the filter is bled and the engine is operated for 15 to 20 minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

FUEL LINES

Flexible fuel lines are used in certain applications to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

Be sure a restricted fitting of the proper size is used to connect the fuel return line to the fuel return manifold. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, the engine should be run long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, connections should be tightened only enough to stop the leak. Also check filter cover bolts for tightness.

TROUBLE SHOOTING CHARTS (Needle Valve Injectors)

Chart 4

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Cause

1. WORN OR ERODED NEEDLE VALVE OR VALVE SEAT IN TIP
2. WORN OR DAMAGED NEEDLE VALVE QUILL
3. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
4. WORN OR BROKEN VALVE SPRING
5. DIRT OR FOREIGN MATERIAL IN INJECTOR

HIGH VALVE OPENING PRESSURE

Probable Cause

6. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
7. CARBON IN TIP ORIFICES

SUGGESTED REMEDY

1. Replace the needle valve and tip assembly.
2. Replace the needle valve and tip assembly.
3. Replace the spring seat.
4. Replace the valve spring.
5. Disassemble the injector and clean the parts.
6. Remove the carbon in the tip with tip rean J 9464 which is especially designed and ground this purpose.
7. Check the hole size of the spray tip orifices. Th using tool J 4298-1 with the proper size wire, clean orifices.

Chart 5

INSUFFICIENT INJECTOR HOLDING TIME

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. CRACKED SPRAY TIP
4. WORN OR ERODED NEEDLE VALVE
5. WORN OR ERODED NEEDLE VALVE SEAT IN SPRAY TIP
6. WORN OR BROKEN NEEDLE VALVE QUILL
7. WORN OR BROKEN VALVE SPRING
8. WORN OR DAMAGED VALVE SPRING SEAT
9. DEFECTIVE SEAL RING
10. BODY PLUG LEAKS
11. FILTER GASKETS LEAK
12. POOR SEALING SURFACES ON FUEL FITTINGS
13. DIRT OR FOREIGN MATERIAL IN INJECTOR

SUGGESTED REMEDY

ap the injector body.

ighten the nut to 75-85 lb-ft torque. Do not exceed specified torque.

5 and 6. Replace the needle valve and spray tip mbly.

eplace the valve spring.

eplace the valve spring seat.

9. Replace the seal ring.

10. Install new body plugs.

11. Replace the filter cap gaskets and tighten the filter caps to 65-75 lb-ft torque.

12. Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.

13. Disassemble the injector and clean the parts.

Chart 6

INCORRECT FUEL OUTPUT

Probable Cause

1. SPRAY TIP OR ORIFICES PARTIALLY PLUGGED
2. SPRAY TIP ORIFICES ENLARGED
3. CARBON BUILDUP IN TIP
4. WORN PLUNGER AND BUSHING
5. WORN OR DAMAGED NEEDLE VALVE QUILL
6. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
7. WORN OR BROKEN VALVE SPRING
8. CRACKED CHECK VALVE CAGE, SPRING CAGE, OR SPRAY TIP
9. CRACKED BUSHING
10. POOR LAPPED SURFACES
11. FOREIGN MATERIAL BETWEEN VALVE AND SEAT
12. RACK AND GEAR NOT IN TIME

SUGGESTED REMEDY

1. Clean the spray tip as outlined under *Clean Injector Parts*.

2. Replace the spray tip assembly.

NOTE: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the *Fuel Output Check Chart*, try changing the spray tip. However, use only a tip specified for the injector being tested.

3. Clean the injector tip with tool J 1243.

4. After the possibility of an incorrect or faulty tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

5. Replace the needle valve.

6. Replace the spring seat.

7. Replace the valve spring.

8. Replace the cracked parts.

9. Replace the plunger and bushing assembly.

10. Re-lap the sealing surfaces.

11. Disassemble the injector and clean the parts.

12. Assemble the gear with the drill spot mark on tooth engaged between the two marked teeth of rack.

FUEL PUMP MAINTENANCE

fuel pump is so constructed as to be inherently ole free. By using clean water-free fuel and taining the fuel filters in good condition, the fuel ɔ will provide long satisfactory service and re very little maintenance.

ever, if the fuel pump fails to function actorily, first check the fuel level in the fuel tank, make sure the fuel supply valve is open. Also for external fuel leaks at the fuel line ections, filter gaskets and air heater lines. Make in that all fuel lines are connected in their proper .

check for a broken pump drive shaft or drive ing. Insert the end of a wire through one of the ɔ flange drain holes, then crank the engine entarily and note whether the wire vibrates. tion will be felt if the pump shaft rotates.

iel pump failures result in no fuel or insufficient being delivered to the fuel injectors and may be ated by uneven running of the engine, excessive tion, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the relief valve and its bore or seat. This permits the fuel oil to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reassemble the valve in the pump.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

CHECKING FUEL FLOW

sconnect the fuel return tube from the fitting at iel tank or source of supply and hold the open f the tube in a convenient receptacle.

rt and run the engine at 1200 rpm and measure uel flow return from the manifold. Refer to n 13.2 for the specified quantity per minute.

merse the end of the fuel tube in the fuel in the iner. Air bubbles rising to the surface of the fuel ndicate air being drawn into the fuel system on ction side of the pump. If air is present, tighten el line connections between the fuel tank and the ump.

he fuel flow is insufficient for satisfactory engine rmance, then:

eplace the element in the fuel strainer. Then tart the engine and run it at 1200 rpm to check ne fuel flow. If the flow is still unsatisfactory, erform Step "b" below.

eplace the element in the fuel filter. If the flow is till unsatisfactory, do as instructed in Step "c".

ubstitute another fuel pump that is known to be n good condition and again check the fuel flow.

When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screw driver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out. If the cylinder has been firing properly there will be a noticeable difference in the sound and operation of the engine when the injector is cut out.

2. Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.

3. Hold a finger over the injector fuel outlet and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector must be removed for service.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	TORQUE (lb-ft)	THREAD SIZE	TORQUE (lb-ft)
1/4 -20	7-9	9/16-12	90-100
1/4 -28	8-10	9/16-18	107-117
5/16-18	13-17	5/8 -11	137-147
5/16-24	15-19	5/8 -18	168-178
3/8 -16	30-35	3/4 -10	240-250
3/8 -24	35-39	3/4 -16	290-300
7/16-14	46-50	7/8 - 9	410-420
7/16-20	57-61	7/8 -14	475-485
1/2 -13	71-75	1 - 8	580-590
1/2 -20	83-93	1 -14	685-695

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)
Governor control housing to flywheel housing	5/16-18	10-12
Blower drive assembly to flywheel housing	3/8 -16	20-25
Injector clamp bolt	3/8 -16	20-25
Fuel line connector	3/8 -24	20-28
Rocker arm bracket bolt	7/16-14	50-55
Governor drive gear retaining nut (in-line engine)	5/8 -18	125-135
Injector filter caps	5/8 -24	65-75
Injector nut (needle valve)	15/16-24	75-85

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR TOOLS	
Injector body reamer	J 21089
Pin vise	J 22800-3
Injector bushing Inspectalite	J 21471
Injector calibrator	J 22410
Adaptor (standard body)	J 7041-61
Seat	J 22410-226
Injector comparator	J 7041
Adaptor	J 7041-61
Adaptor	J 7041-72
Adaptor	J 7041-88

SERVICE TOOLS

L NAME	TOOL NO.
daptor	J 7041-130
ctor holding fixture	J 22396
ctor nut tip seat reamer (needle valve)	J 9418-1
ctor nut tip seat reamer (needle valve)	J 9418-5
ctor service tool set	J 1241-05
pray tip cleaner	J 1243
pray tip remover and bushing cleaner	J 1291-02
jector spray tip hole cleaner	J 4298-1
jector nut socket wrench	J 4983-01
jector nut tip seat reamer	J 4986-01
jector valve seat deburring tool	J 7174
jector rack hole brush	J 8150
jector body brush	J 8152
jector wire honing stone	J 8170
ctor test oil (one gallon)	J 8130
ctor tester	J 9787
est block	J 9787-49
daptor	J 8538-10
ctor tip carbon remover (needle valve)	J 9464-01
pecial drill	J 9464-1
ctor tip concentricity gage	J 5119
ing block set	J 22090
ing compound	J 23038
l Ethyl Keystone solvent (one gallon)	J 8257
dle valve injector auxiliary tester	J 22640
dle valve lift gage	J 9462-01
hing stick set	J 22964
et	J 8932-01
g tester	J 9666

ECTOR TUBE TOOLS

der head holding plate set	J 3087-01
tor tube service tool set	J 22525

VERNOR TOOLS

rol link lever bearing installer	J 8985
rnor cover bearing installer	J 21068
rnor cover bearing remover	J 21967
rnor weight carrier installer	J 8984
led nut	J 21995-1
wrench	J 5895
	J 21995-2
ner wrench	J 5345-5

SECTION 3

AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

In the scavenging process employed in the Series 53 engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, therefore, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Fig. 1. The continuous discharge of fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners.

The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

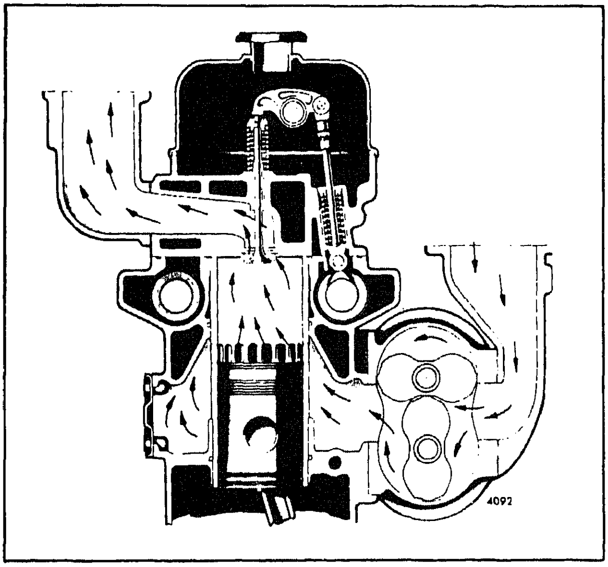


Fig. 1 - Air Flow Through Blower and Engine (In-Line Engine)

AIR SILENCER

In-Line Engines

The air silencer (Fig. 1) is attached to the intake side of the blower housing to reduce the sound level of the air entering the blower.

A perforated sheet metal partition divides the silencer into two sections. The engine side of the partition and the outer shell forms an air duct the entire length of the silencer. Air enters this duct from both ends and flows to the blower intake opening at the center. The area between the partition and the outer side of the silencer is filled with sound absorbent, flame-proof, felted cotton waste.

An air intake (blower) screen is used between the air silencer and the blower housing to prevent foreign objects from entering the blower.

Remove and Install Air Silencer

While no servicing is required on the air silencer, it may be necessary at times to remove it to clean or replace the blower screen or to perform other service operations.

1. Support the silencer and remove the attaching bolts and lock washers. Then remove the silencer and the blower screen.

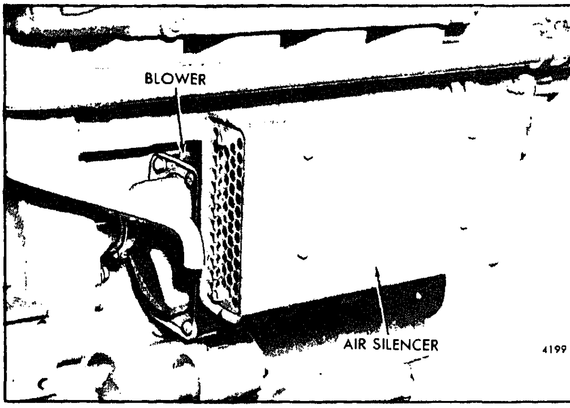


Fig. 1 - Air Silencer Mounted on In-Line Engine

2. Clean the blower screen with fuel oil and dry it compressed air.

4. Place the lock washers over the bolts and slide bolts through the bolt holes in the silencer.

5. Place the blower screen (In-line engines) over projecting bolts and position the silencer against blower housing. Then tighten the bolts.

AIR SHUT-DOWN HOUSING

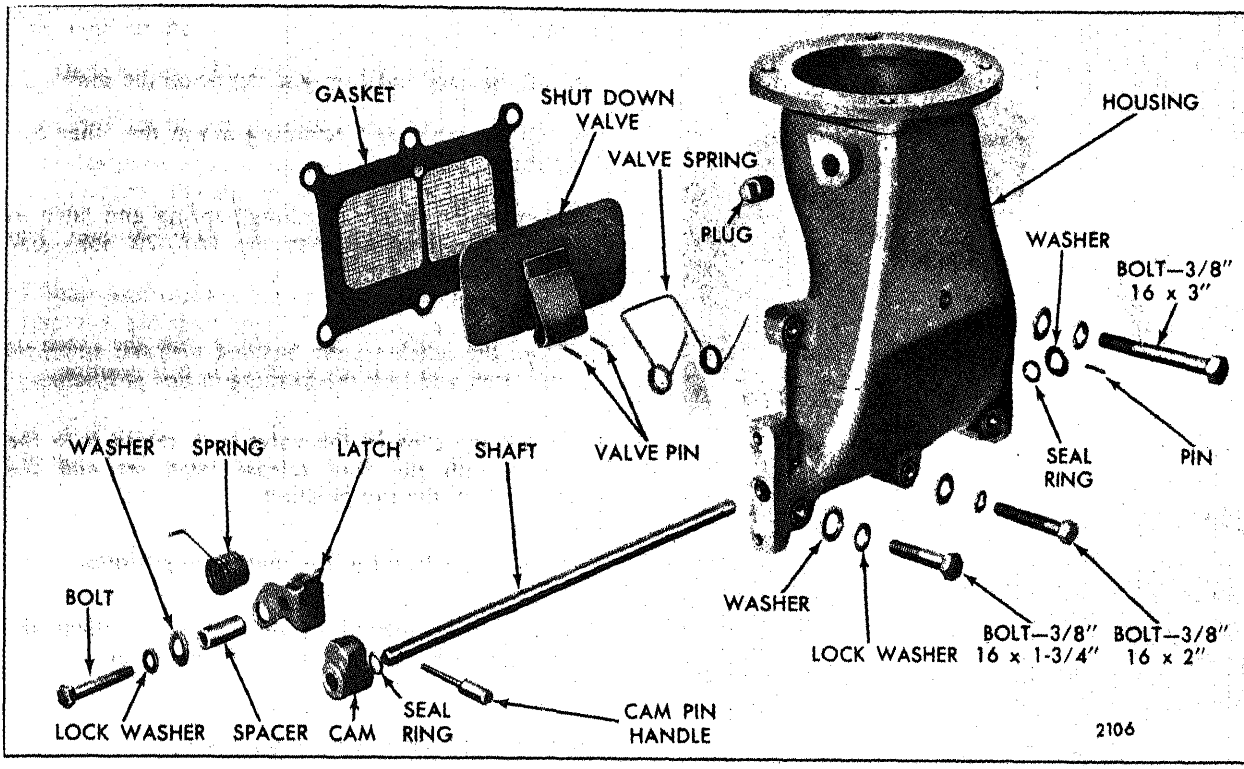


Fig. 1 - Typical In-Line Air Shut-Down Housing Details and Relative Location of Parts

The air shut-down housing on the in-line engine is mounted on the side of the blower.

The air shut-down housing contains an air shut-off valve that shuts off the air supply and stops the engine whenever abnormal operating conditions require an emergency shut-down.

Remove Air Shut-Down Housing

1. Disconnect and remove the air ducts between the air cleaner and the air shut-down housing.

2. Disconnect the control wire from the air shut-off cam pin handle.

3. Remove the bolts and washers that retain the housing to the blower and remove the housing from the blower. Remove the air shut-down housing gasket from the blower.

> **NOTE:** Cover the blower opening to prevent dirt or foreign material from entering the blower.

Disassemble Air Shut-Down Housing

Refer to Fig. 1 and disassemble the air shut-down

1. Remove the pin from the end of the shut-do shaft. Then remove the washer from the shaft and t seal ring from the housing.

2. Remove the two pins that secure the shut-off va to the shaft.

3. Remove the bolt, lock washer and plain wasl which attach the latch to the housing. Then remove latch, latch spring and spacer.

4. Note the position of the air shut-off valve spri and the valve (Fig. 2); then withdraw the shaft fr the housing to release the valve and the spri Remove the valve and spring and the seal ring fr the housing.

5. Remove the cam pin handle and withdraw the c from the shaft.

Inspection

Clean all of the parts thoroughly, including the blov screen, with fuel oil and dry them with compressed a Inspect the parts for wear or damage. The face of shut-down valve must be perfectly flat to assure a ti

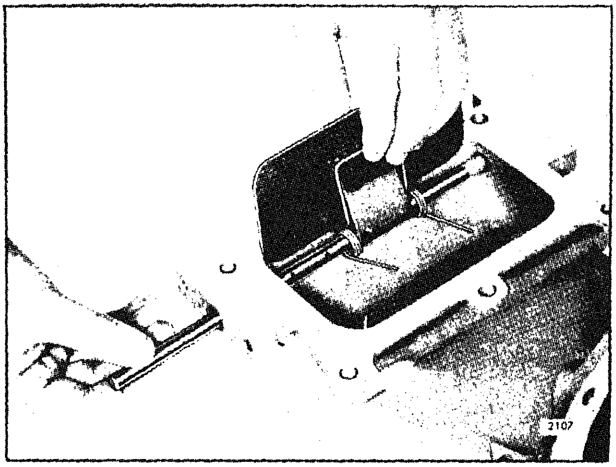
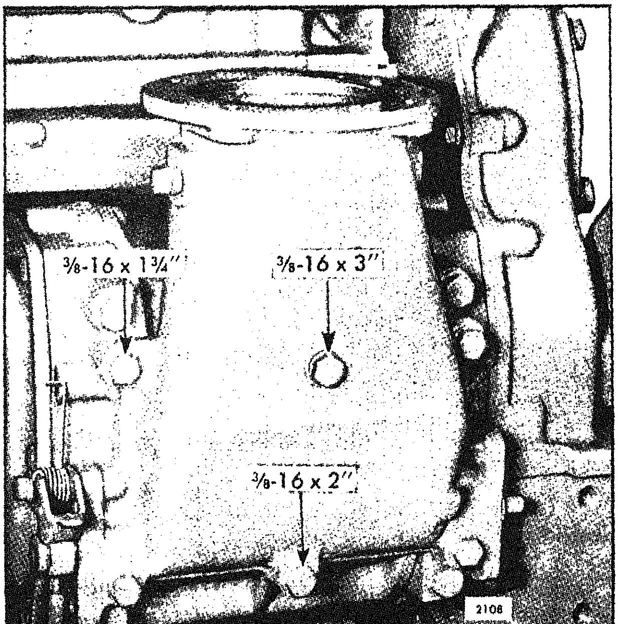


Fig. 2 - Installing Air Shut-Off Valve Spring and Valve

Assemble Air Shut-Down Assembly

The holes for the cam pin handle and the retaining pins must be drilled, using a 1/8" diameter drill, at the time a new service shaft or air shut-off valve(s) is assembled. The valve(s) must be in the same plane within .03" when in the stop position (flush with the housing face). Refer to Figs. 1 and 2 and proceed as follows:

1. Place the valve(s) and spring in position in the housing (Fig. 2) and slip the shaft in place. The shaft must extend .70" from the side of the housing where the shut-down latch is assembled.



2. Install a new seal ring at each end of the shaft. sure the seals are seated in the counterbores of housing.

3. Install the cam and cam pin handle on the shaft.

4. Install a washer and retaining pin at the other of the shaft.

5. Assemble the spacer (bushing), spring and latch the shut-down housing with the 1/4"-20 bolt, l washer and plain washer.

a. Align the notch on the bushing with the notch the latch and lock the bushing in this position.

b. Install the pins in the valve(s) to retain it to shaft with the cam release latch set and valve(s) in the run position.

c. Level the valve(s) in the shut-down position.

d. Adjust the bushing so the valve(s) contacts housing when the cam release latch is set.

Install Air Shut-Down Housing (In-Line Engines)

1. Place the blower screen and gasket assembly position with the screen side of the assembly tow the blower.

2. Refer to Figs. 1 and 3 and secure the air shut-d housing to the blower with bolts, washers and l washers as follows:

a. Install and finger tighten the six attaching bolts shown in Fig. 3.

b. Tighten the two center bolts to 16-20 lb-ft torque.

c. Then tighten the four corner bolts to 16-20 lb-ft torque.

CAUTION: A power wrench should not be used to tighten the above bolts.

3. Reset the air shut-down to the run position.

4. Start and run the engine at idle speed and no load. Trip the air shut-down. If the engine does not stop, check it for air leakage between the valve and the gasket. If necessary, reposition the valve.

BLOWER

IN-LINE ENGINES

The blower supplies the fresh air required for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow double-lobe rotors revolve in a housing bolted to the side of the in-line engines (Fig. 1)

The revolving motion of the rotors provides a continuous and uniform displacement of air.

The blower rotors are pinned to the rotor shafts. The rotor shafts are steel and the blower end plates are aluminum, providing for a compatible bearing arrangement.

Gears located on the splined end of the rotor shafts space the rotor lobes with a close tolerance. Since the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip type oil seals are used in both the front and rear end plates on current engines. The seals prevent air leakage past the blower rotor shaft bearing surfaces and also keep the oil, used for lubricating the blower rotor gears, from entering the rotor compartment. Former blowers used a ring type oil seal consisting of a fiber washer, "0" ring, retainer and seal spring in each end of the blower rotors.

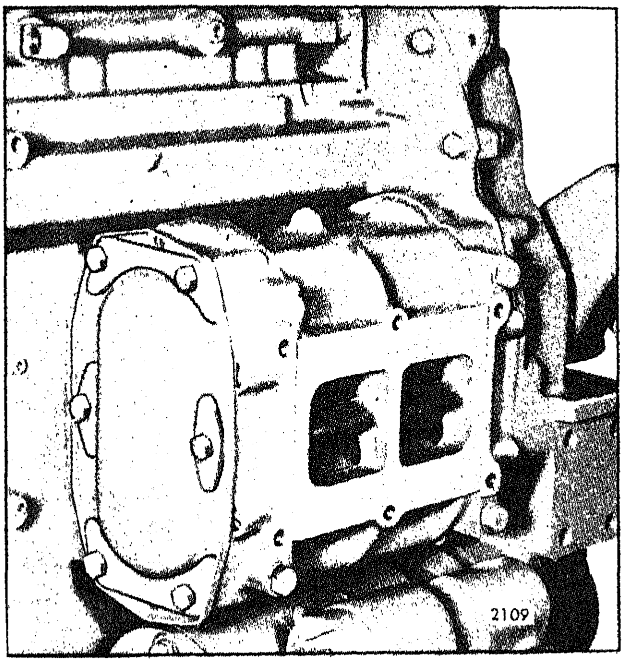


Fig. 1 - Blower Mounting (3-53 Engine)

Inspect Blower (Attached to Engine)

The blower may be inspected without removing it from the engine. However, the air cleaner and the air inlet housing must be removed.

> **CAUTION:** When inspecting the blower with the engine running, keep your fingers and clothing away from the moving parts of the blower and run the engine at low speeds only.

r chips drawn through the blower will make ratches in the rotors and housing. Burrs around brasions may cause interference between the or between the rotors and the blower housing.

oil seals are usually indicated by the presence of the blower rotors or inside surfaces of the housing. Run the engine at low speed and a light into the rotor compartment and toward d plates and the oil seals. A thin film of oil ng away from a seal indicates an oil leak.

n blower drive resulting in a loose, rattling within the blower may be detected by running gine at approximately 500 rpm.

rotor shafts or worn rotor shaft bearing surfaces ult in contact between the rotor lobes, the rotors e end plates, or the rotors and the housing.

ve backlash between the blower rotor gears results in the rotor lobes rubbing throughout ntire length.

e Blower

removing the blower from the engine, remove shut-down housing as outlined in Section 3.3.

3-53 ENGINE BLOWER

move the six bolts, special washers and cement plates which secure the blower to the end plate and the flywheel housing. *Note the n of the two shorter bolts.* Then remove the front te cover and gasket from the blower.

2. Remove the four blower-to-block bolts and special washers and lift the blower away from the engine.

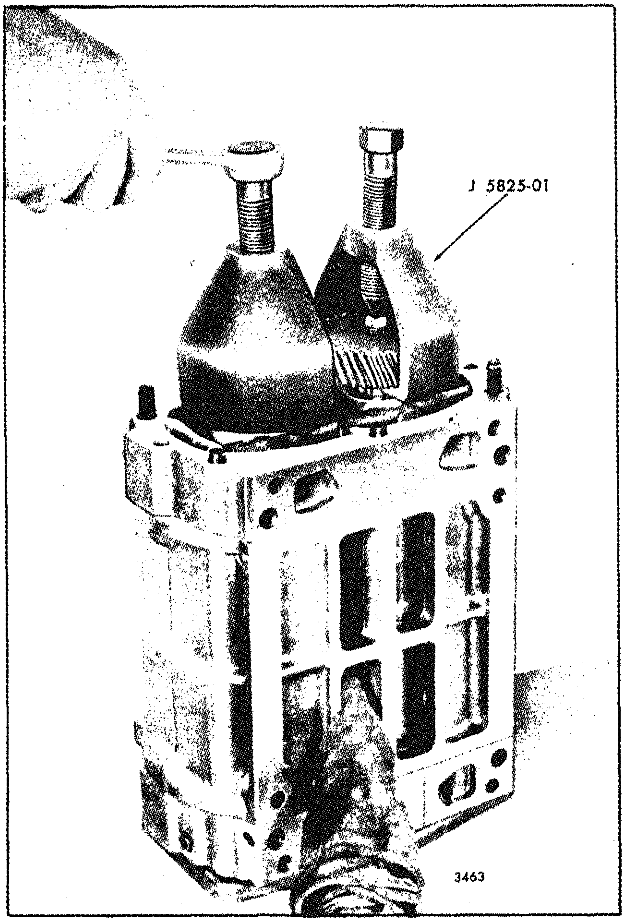


Fig. 5 - Removing Blower Rotor Gears

Disassemble Blower

3-53 ENGINE BLOWER

1. Wedge a clean cloth between the rotors to pre their turning. Then remove the blower gear retai bolts and washers.

2. For identification, mark the R.H. helix gear. T remove the gears with pullers J 5825-01 as follows:

a. With the pullers in place under the gears (Fig place a brass bar, approximately 1 " long 5/8 " diameter, between the point of each p bolt and blower rotor shaft.

CAUTION: If the brass bar is larger than 5/8 " diameter, the serrations in the blower driv gear may be damaged.

b. Alternately turn the bolt in each puller until gears are off the shafts.

3. Remove the rotor shims and the gear spacers place them with their respective gears to ensure co re-assembly.

4. At the other end of the blower, remove the t thrust plate bolts, the thrust plate and three spa from the front end plate. Remove the bolts and th washers (refer to Fig. 7).

5. Remove the two screws that retain the end pla the blower housing. Tap the end plate off of the d pins and housing with a soft (plastic) hammer, b careful not to damage the mating surfaces of the plate and the housing.

6. Remove the rotors from the blower housing.

7. Remove the retaining screws and remove the end plate as in Step 5.

8. Remove and discard the lip type oil seals from end plates on current blowers. Remove the washer, "O" ring, retainer and retainer spring each rotor shaft on former blowers.

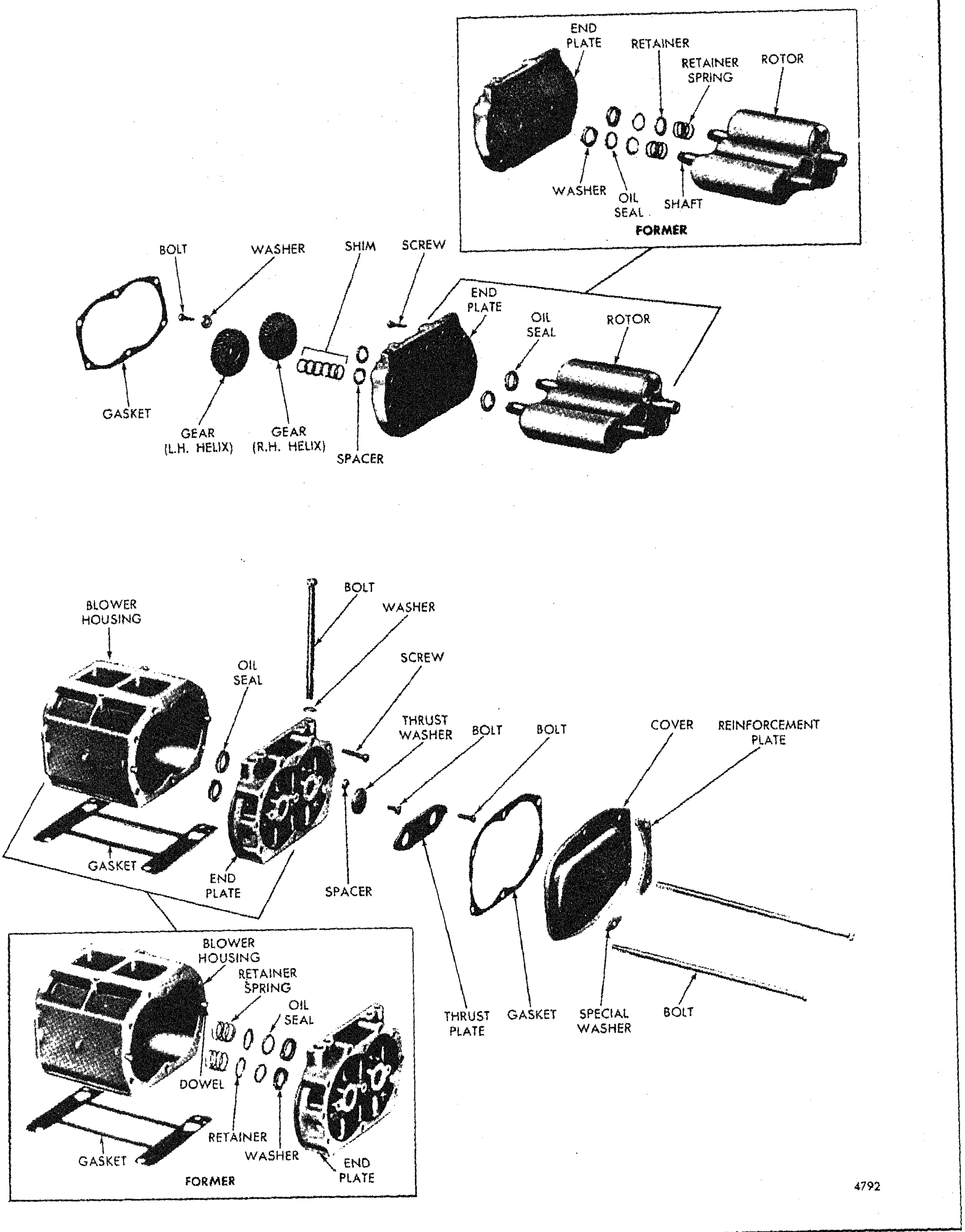


Fig. 7 · Typical Blower Details and Relative Location of Parts (3-53 Engine Blower)

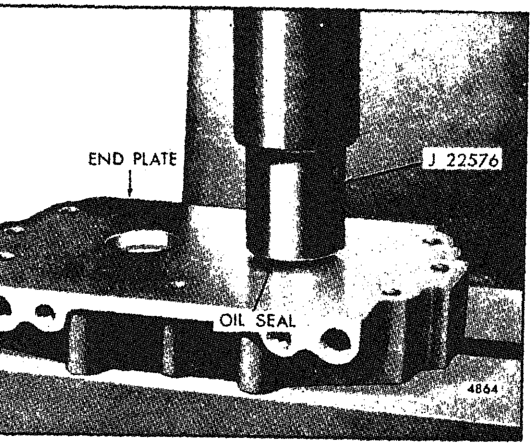


Fig. 9 - Installing Lip Type Oil Seal in End Plate

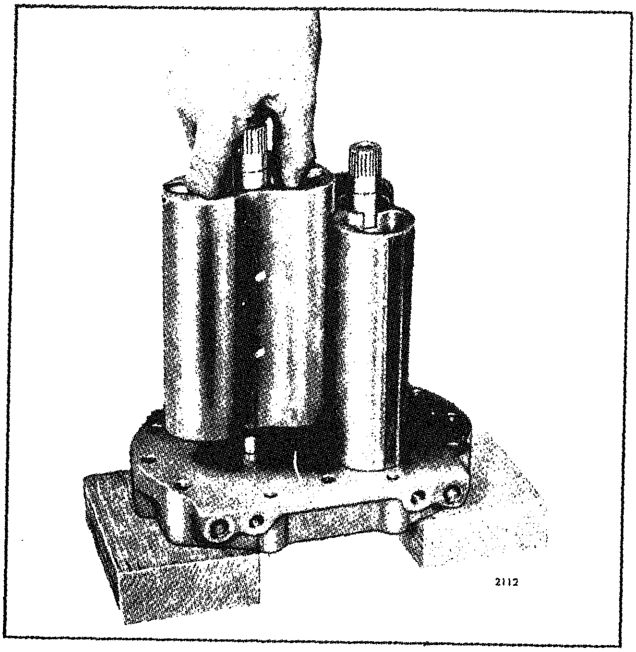
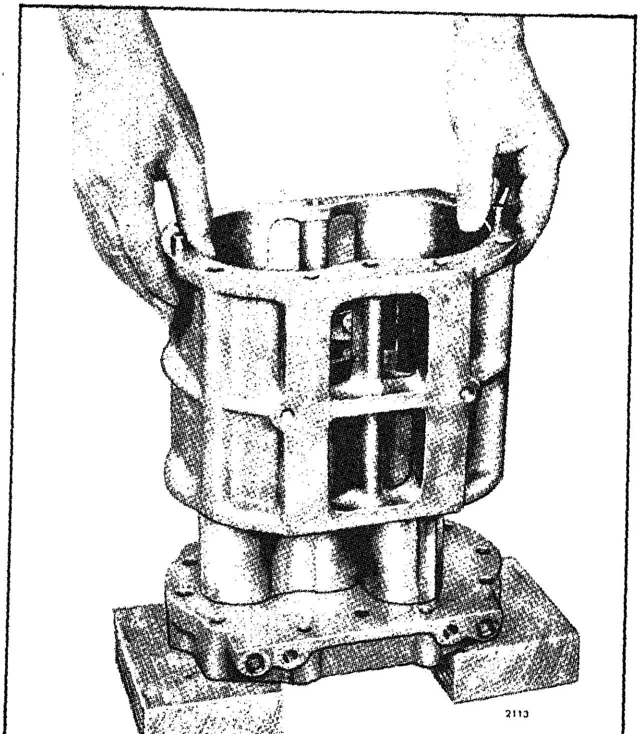


Fig. 10 - Installing Blower Rotors in Front End Plate



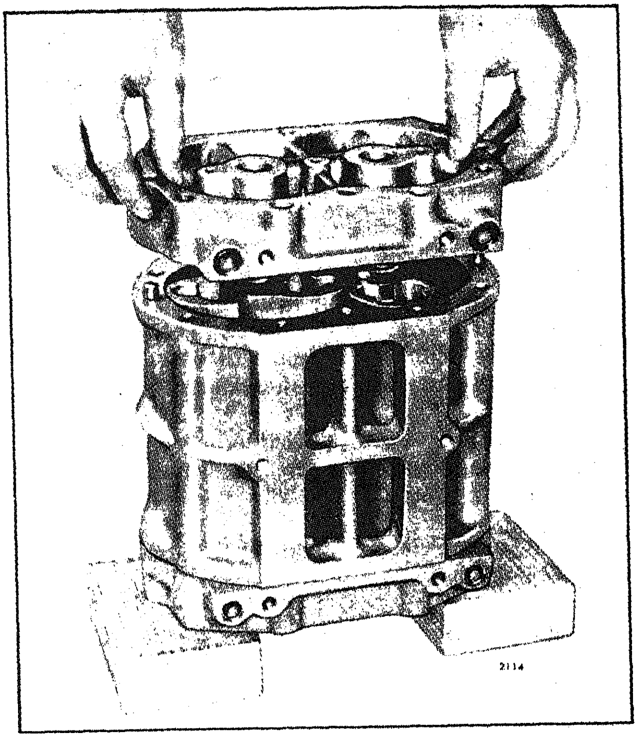


Fig. 12 · Installing Rear End Plate

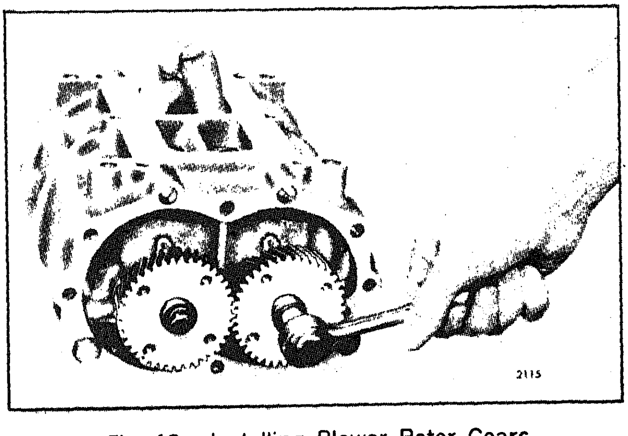


Fig. 13 · Installing Blower Rotor Gears

Inspection

Clean and dry all of the parts thoroughly.

The finished inside face of each end plate mus smooth and flat. Slight scoring may be cleaned up a fine grit emery cloth. If the surface is badly sc replace the end plate.

Inspect the surfaces of the rotors and the bl housing. Remove burrs or scratches with an oil sto

Examine the rotor shaft, gear or drive coupling burred or worn serrations.

Inspect the blower gears for excessive wear or dam

Check the bearing and oil seal contact surfaces o rotor shafts and end plates for scoring, wear or nic

If an oil seal sleeve is used on the rotor shaft, it ca replaced as follows:

a. Place sleeve remover J 23679-2 over the shaft and behind the oil seal sleeve.

b. Back out the center screw of one gear p J 21672-7 and attach the puller to the s remover with three 1/4"-20 x 3" bolts anc washers.

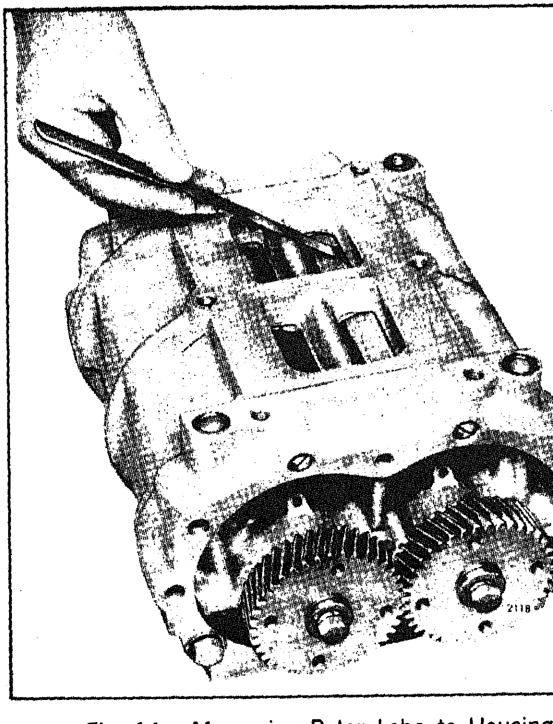


Fig. 14 · Measuring Rotor Lobe to Housing Clearance

c. Turn the puller screw clockwise and pull the sleeve off of the shaft.

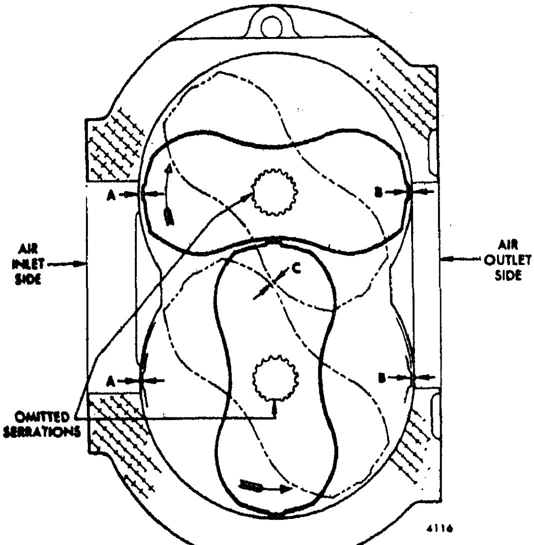
d. Support the rotor, gear end up, on the bed of an arbor press.

e. Start a new sleeve straight on the shaft.

f. Place sleeve installer J 23679-1 on top of the sleeve and press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft.

NOTE: The step in the sleeve installer properly positions the sleeve on the shaft.

To replace the former "0" ring oil seals by the current lip type oil seals, rework the end plates by following the instructions given in *Shop Notes* in Section 3.0.



-	A	B	C
3-53	.0075"	.004"	.010"

MINIMUM BLOWER ROTOR CLEARANCES

Fig. 15 - Minimum Blower Rotor Clearance

Assemble Blower

Refer to Fig . 7 and assemble the blowe follows:

1. Install new lip type oil seals in each end plat *current blowers* as follows:

a. Place the end plate on the bed of an arbor pres

b. Lubricate the outer diameter of the seal and, u installer J 22576, press the seal (lip facing do into the counterbored hole until the shoulder the installer contacts the end plate (Fig. 9).

NOTE: A step on the seal installer will position the oil seal below the finished face of the end plate within the .002 " to .008 " specified.

2. Install the ring type oil seals on the rotor shaft *former blowers* as follows:

a. Install a retainer spring on each shaft of e rotor. Then place an "0" ring retainer (dis side up) on each spring.

b. Lubricate the "O" rings with clean engine then slide one ring on each shaft.

c. Lubricate and place a seal on each shaft. Note the tangs on each seal are flush with one sid the seal; this side of the seal must face toward rotor.

3. Place the front end plate on two wood blocks. T install the rotors, gear end up, on the end p (Fig. 10). On the former blowers, be sure that the type oil seals are properly positioned on the rotors.

4. Install the blower housing over the rotors (Fig. 1

NOTE: To prevent inadequate lubrication or low oil pressure, care must be exercised in the assembly of the front and rear blower end plates to the blower housing. The rear end plate for the *3-53 blower* does not have tapped holes for the thrust washer plate bolts and no thrust washer lubricating oil holes.

5. Place the rear end plate over the rotor sh (Fig. 12). On the former blowers, be sure that the type oil seals are properly positioned on the ro Then secure each end plate to the 3-53 blower hou with two end plate retaining screws and two c

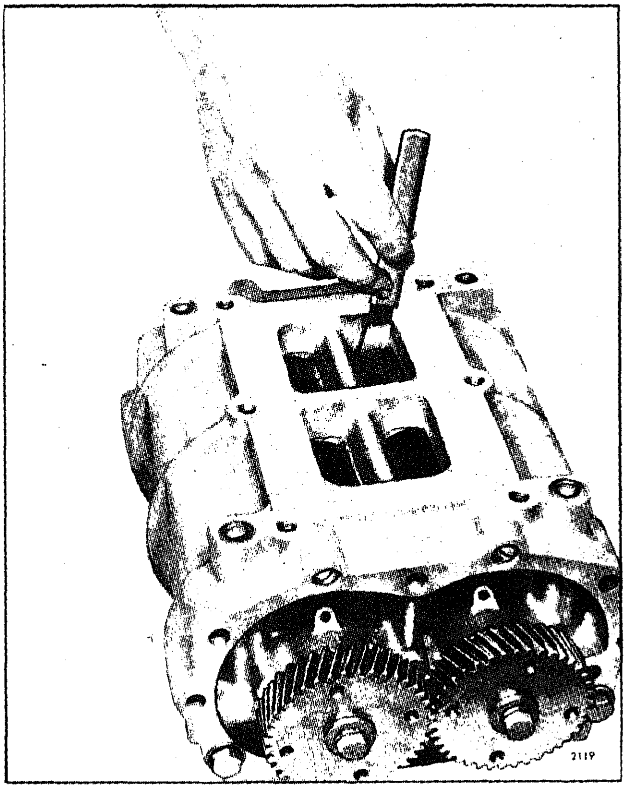


Fig. 16 · Measuring Rotor Lobe to End Plate Clearance

bolts and plain washers.

6. Attach the two thrust washers to the front end of the blower with the washer retaining bolts. If 5/16 ″-24 bolts are used, tighten them to 25-30 lb-ft torque; if 3/8 ″ - 24 bolts are used, tighten them to 54-59 lb-ft torque.

7. Attach the three spacers and the thrust plate to the front end of the blower. Tighten the three bolts to 7-9 lb-ft torque. Then check the clearance between the thrust plate and the thrust washers. The specified clearance is .001 ″ to .003 ″.

> **NOTE:** The current thrust plate is .260 ″ thick. The former plate was .180 ″ thick.

8. Position the rotors so that the missing serrations on the gear end of the rotor shafts are 90 ° apart. This is accomplished by placing the rotors in a "T" shape, with the missing serration in the upper rotor facing to the left and the missing serration in the lower rotor facing toward the bottom (Fig. 14). Install the shims and spacers in the counterbore in the rear face of the rotor gears. Then place the gears on the ends of the

shafts with the missing serrations in alignmen the missing serrations on the shafts.

9. Tap the gears lightly with a soft hammer them on the shafts. Then rotate the gears un punch marks on the face of the gears match. marks do not match, re-position the gears.

10. Wedge a clean cloth between the blower Use the gear retaining bolts and plain washers t the gears on the rotor shafts (Fig. 13). Turn th uniformly until the gears are tight agains shoulders on the shafts.

11. Remove the gear retaining bolts and washers proceed as follows:

> **3-53 Blower** -- Place the gear washers gears and start the gear retaining bolts in the shafts. Tighten the bolts to 25-30 lb-ft torque.

12. Check the backlash between the blower using a suitable dial indicator. The specified ba is .0005 ″ to .0025 ″ with new gears or a maxim .0035 ″ with used gears.

13. Time Blower Rotors

After the blower rotors and gears have been ins the blower rotors must be timed. When pr positioned, the blower rotors run with a clearance between the rotor lobes and with a clearance between the lobes and the walls housing.

The clearances between the rotors may be estab by moving one of the helical gears out or in shaft relative to the other gear by adding or rem shims between the gear hub and the rotor spacer

It is preferable to measure the clearances with a gage comprised of two or more feelers, si combination is more flexible than a single feele Take measurements from both the inlet and sides of the blower.

a. Measure the clearance between the rotor lob

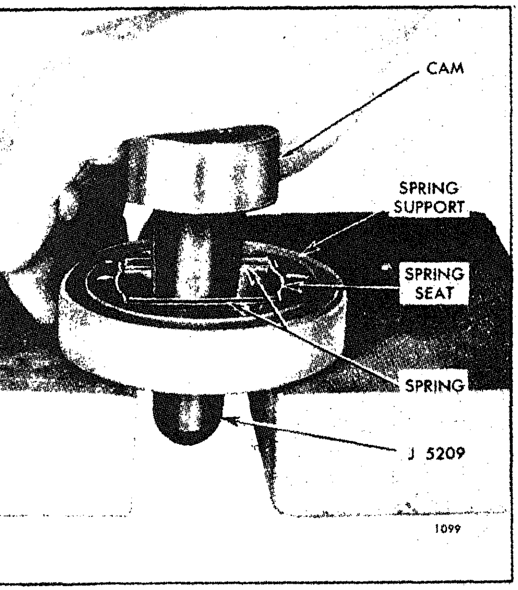


Fig. 17 · Inserting Cam in Blower Drive Support

housing as shown in Fig. 14. Take measure- ts across the entire length of each rotor lobe e certain that a minimum clearance of .004 " ts at the *air outlet side* of all blowers and a imum clearance of .0075 " (in-line engine ver) exists at the *nlet side* of the blower (Fig. 15).

sure the clearance between the rotor lobes, ss the length of the lobes, in a similar ner. By rotating the gears, position the lobes hat they are at their closest relative position . 15). The clearance between the lobes should minimum of .010 ".

sure the clearance between the end of the r and the blower end plate as shown in 16. Refer to the chart for the required imum clearances.

: Push and hold the rotor toward the end at which the clearance is being measured.

ning the rotors, complete assembly of the

ve the bolts and washers used to temporarily e front end plate to the housing. Then install end plate to the blower with six bolts and vashers and two reinforcement plates and ne bolts to 20-25 lb-ft torque.

BLOWER ROTOR END CLEARANCES (Minimum)		
Engine	Front End Plate	Rear End Plate
3-53	.006"	.008"

15. Assemble the blower drive spring support as follows:

a. Place the drive spring support on two blocks of wood (Fig. 17).

b. Position the drive spring seats in the support.

c. Apply grease to the springs to hold the leaves together, then slide the two spring packs (15 leaves per pack) in place.

d. Place the blower drive cam over the end of tool J 5209, insert the tool between the spring packs and press the cam in place.

16. Install the drive spring support coupling on the rotor gear at the rear end of the blower.

17. Secure the cam retainer to the coupling with four 1/4 "-28 bolts and tighten them to 14-18 lb-ft torque.

19.

Install the rear end plate cover and gasket and secure the cover and end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20-25 lb-ft torque.

Install Blower

Examine the inside of the blower for any foreign material. Also revolve the rotors by hand to be sure that they turn freely. Then install the blower on the engine as follows:

3-53 ENGINE BLOWER

1. Affix a new blower-to-block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 4300, or equivalent, only on the block side of the gasket.

2. Position the blower front end plate and gasket on the end of the blower and install six bolts with two special washers on the center bolts and the reinforcement plates on the two top and two bottom bolts. Install a new engine ena plate to blower over the threaded ends of the bolts. Apply Scotc Rubber Adhesive No. 4300, or equivalent, engine end plate side of the gasket.

NOTE: The current front and rear end pl gaskets are identical and may be used in eit position. Formerly these gaskets were interchangeable due to a difference in thickne

3. Place the blower on the cylinder block lo flanges and, while holding the blower in place, the six bolts finger tight in the rear engine end and flywheel housing. Then install the blower-to mounting bolts and washers and tighten them to lb-ft torque.

4. Tighten the center blower-to-end plate bolt and then the top and bottom bolts to 20-25 torque. Then tighten the blower-to-block bolts to lb-ft torque.

5. Check the backlash between the upper roto and the camshaft or balance shaft gear. The ba should be .003 " to .007 ".

6. Install the air shut-down housing (Section 3.3)

SHOP NOTES - TROUBLE SHOOTING - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

REWORKING BLOWER END PLATES FOR IN-LINE ENGINES

On non-turbocharged engines built prior to serial number 3D-34008 when oil is detected on the blower rotors or inside surface of the housing, the blower end plate can be reworked to accommodate a new lip type oil seal or a steel insert.

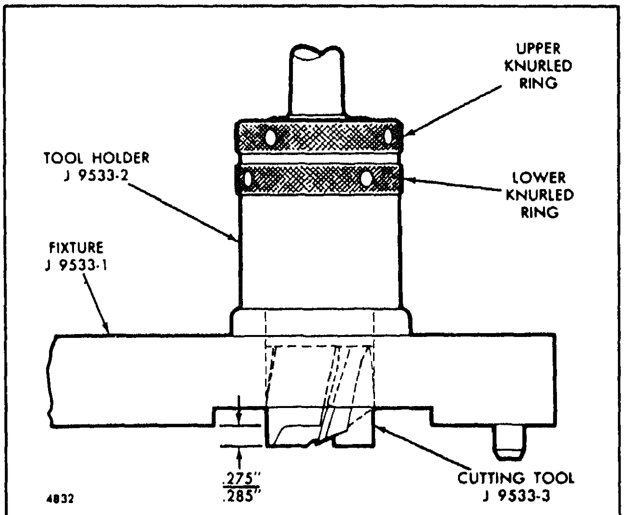
NOTE: Slight phonographic grooves can actually improve sealing. Unless wear is considerable and oil leakage is evident, the end plate need not be reworked.

Rework Blower End Plate

Use tool kit J 9533 to rework the end plate.

NOTE: On some prior serviced blowers, the end plates may have been reworked to accommodate a steel insert. In such cases, proceed as follows but omit Step 10.

1. Adjust the tool holder J 9533-2 and cutting tool J 9533-3 for the proper counterbore depth as follows:



a. Insert the rough cutting tool J 9533-3 in the holder as shown in Fig. 1.

b. Position the holder and the cutting tool in fixture J 9533-1.

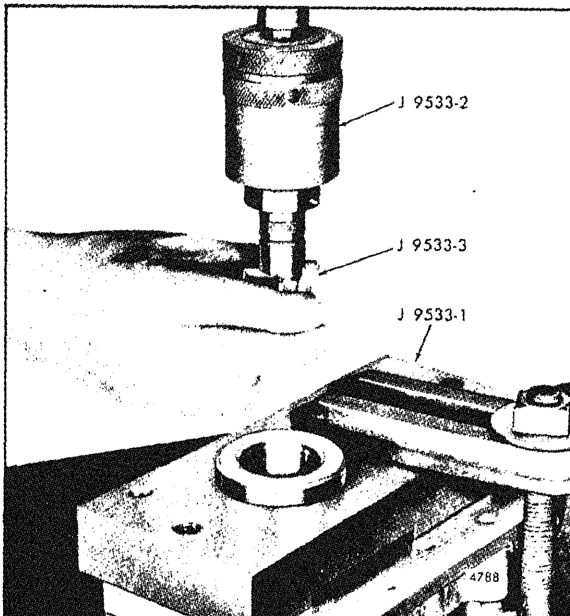
c. Loosen the "upper knurled ring" on the holder.

d. Rotate the "lower knurled ring" to raise or lo the cutting tool. Turn the "lower knurled ri until there is a distance of .275 " - .285 " betw the end of the cutting tool and the bottom of fixture.

e. Tighten the "upper knurled ring".

2. Place fixture J 9533-1 on the blower end plate.

3. Clamp the fixture and the end plate loosely to bed of a drill press.



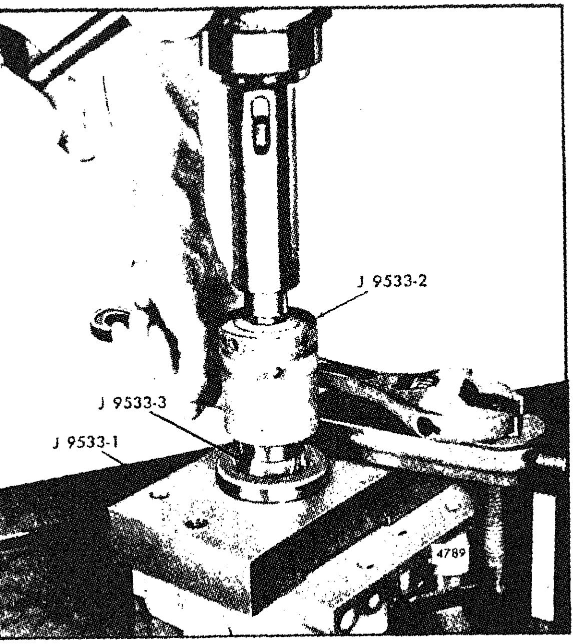


Fig. 3 - Positioning Cutting Tool in Fixture Guide

Install tool holder J 9533-2 in the drill press and ert the rough cutting tool J 9533-3 in the holder g. 2).

Position the cutting tool in the fixture guide as wn in Fig. 3. Operate the drill press at 75-100 rpm as to center the cutting tool in the rotor shaft hole. hten the clamp.

Lubricate the cutting tool and the area of the end te that is being reworked with a lubricant (oleum or l oil).

Operate the drill press at 300-350 rpm and slowly nterbore the hole until the collar of the tool holder approximately 1/16 " from the fixture guide. Then uce the speed of the drill press to 75-100 rpm and tinue counterboring until the collar contacts the top he guide.

NOTE: Raise the cutting tool periodically during the drilling operation and apply additional lubricant.

Stop the drill press and remove the rough cutting l.

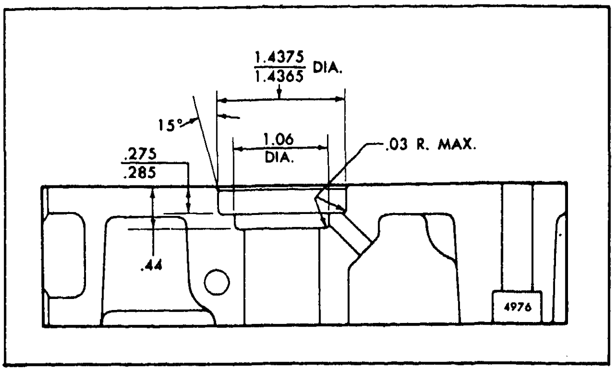


Fig. 4 - End Plate Oil Drain Back Counterbore

9. Insert the finish cutting tool J 9533-4 in the holder. Lubricate the cutting tool and the end plate. Operate the drill press at 75-100 rpm and finish-cut the counterbore. Feed the cutting tool into the work slowly.

10. Remove the finish cutting tool and install an end mill to machine the additional 1.06 " diameter counterbore. The total depth of the combined counterbores is .44 " (Fig. 4). The additional counterbore provides proper oil drain back from the oil seal area.

11. Remove the fixture from the end plate. Wipe the cuttings from the end plate and fixture and dry the plate and fixture with compressed air. Remove any burrs from the edge of the oil hole.

12. Thoroughly clean the cutting tool and the end mill flutes and repeat the procedures for the adjacent rotor shaft hole.

13. Place the blower end plate on the bed of an arbor press. Use installer J 22576 to press the seal (lip facing down) into the counterbored hole until the shoulder on the installer contacts the end plate.

> **NOTE:** A step under the shoulder of the installer will position the oil seal below the finished face of the end plate within the .002 " to .008 " specified.

Steel Inserts

To install steel inserts in the blower end plates, follow Steps 1 through 9 and 11 and 12. Press the inserts flush to .003 " above the blower end plate surface.

SPECIFICATIONS

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PART (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Blower			
Backlash--rotor gears (all)	.0005 ″	.0025 ″	.0035 ″
Backlash between upper rotor and camshaft or balance shaft gear (3-53)	.0030 ″	.0070 ″	
Backlash between blower drive gear and camshaft gear	.0030 ″	.0070 ″	
Clearances:			
Thrust plate and thrust washer (in-line)	.0010 ″	.0030 ″	
Rotor to air outlet side of housing:			
In-line	.0040 ″		
Rotor to air inlet side of housing:			
In-line	.0075 ″		
Rotor to front end plate:			
In-line	.0060 ″		

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	TORQUE (lb-ft)	THREAD SIZE	TORQUE (lb-ft)
1/4 -20	7-9	9/16-12	90-100
1/4 -28	8-10	9/16-18	107-117
5/16-18	13-17	5/8 -11	137-147
5/16-24	15-19	5/8 -18	168-178
3/8 -16	30-35	3/4 -10	240-250
3/8 -24	35-39	3/4 -16	290-300
7/16-14	46-50	7/8 - 9	410-420
7/16-20	57-61	7/8 -14	475-485
1/2 -13	71-75	1 - 8	580-590
1/2 -20	83-93	1 -14	685-695

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)
Blower drive coupling to rotor gear bolt (in-line)	1/4 ″-28	14-18
Blower drive gear pilot bolt (in-line)	5/16 ″-24	25-30
Blower timing gear-to-rotor shaft bolts (in-line and 6V)	5/16 ″-24	25-30
Blower thrust washer retaining bolt (in-line)	5/16 ″-24	25-30
Air inlet adaptor-to-blower bolts	3/8 ″ -16	16-20
Air inlet housing-to-adaptor or blower housing bolts	3/8 ″ -16	16-20
Governor-to-blower front end plate bolts	3/8 ″ -16	20-24
Blower drive support-to-blower rear end plate bolts	3/8 ″ -16	20-24
Flywheel housing-to-blower drive support bolts	3/8 ″ -16	20-24
Blower drive gear cover bolt	3/8 ″ -16	20-24
Blower-to-engine rear end plate and flywheel housing bolts (3-53)	3/8 ″ -16	20-25
	3/8 ″ -24	20-25
Blower thrust washer retaining bolt (in-line)	3/8 ″ -24	54-59
Blower end plate-to-block bolts	7/16 ″-14	55-60

SERVICE TOOLS

TOOL NAME	TOOL NO.
BLOWER	
Blower clearance feeler gage set	J 1698-02
Blower drive cam installer	J 5209
Gear puller (3-53)	J 5825-01
Handle	J 7079-2
Blower end plate counterbore set:	J 9533
Fixture	J 9533-1
Cutting tool - holder	J 9533-2
Cutting tool - roughing	J 9533-3
Cutting tool - finishing	J 9533-4
Blower service tool set:	J 21672
Gear pullers	J 21672-7
Rotor shaft ball bearing installer	J 21672-10
Oil seal and bearing remover	J 21672-11
Oil seal and roller bearing installer	J 21672-12
Oil seal sleeve and roller bearing inner race installer	J 21672-16
Spanner wrench	J 21672-17
Oil seal sleeve and roller bearing inner race remover	J 21672-20
Oil seal installer	J 22576
Oil seal sleeve installer (in-line)	J 23679-1
Oil seal sleeve remover (in-line)	J 23679-2

SECTION 4

LUBRICATION SYSTEM

CONTENTS

LUBRICATION SYSTEM

IN-LINE ENGINES

The engine lubrication systems, illustrated in Figs. 1 and 2, include an oil intake screen and tube assembly, an oil pump, an oil pressure regulator valve, a full flow oil filter with a by-pass valve, an oil cooler and oil cooler by-pass valve.

The rotor type oil pump is bolted to the back of the engine lower front cover and is driven directly by the crankshaft.

Lubricating oil from the pump passes from the lower front engine cover through short gallery passages in the cylinder block. From the block, the oil flows to the full flow filter, then through the oil cooler and back into the front engine cover and cylinder block oil galleries for distribution to the various engine bearings. The drain from the cylinder head and other engine parts leads back to the oil pan.

Clean engine oil is assured at all times by the use of a replaceable element type full flow filter. With this type filter, which is installed between the oil pump and the oil cooler, all of the oil is filtered before entering the engine. Should the filter become plugged, the oil will flow through a by-pass valve, which opens at approximately 18-21 psi, directly to the oil cooler.

On current engines, the oil cooler by-pass valve is located on the right-hand side of the engine front cover and the oil pressure regulator valve is located on the left-hand side as viewed from the rear of the engine (Figs. 1 and 2). On former engines, both valves were located on the right-hand side of the cover (Figs. 1 and 2).

If the cooler becomes plugged, the oil flow will be to a by-pass valve in the lower engine front cover and then to the cylinder block oil galleries. The by-pass valve opens at approximately 52 psi in the current In-line engines. In the former In-line engines, the by-pass valve opens at approximately 30 psi.

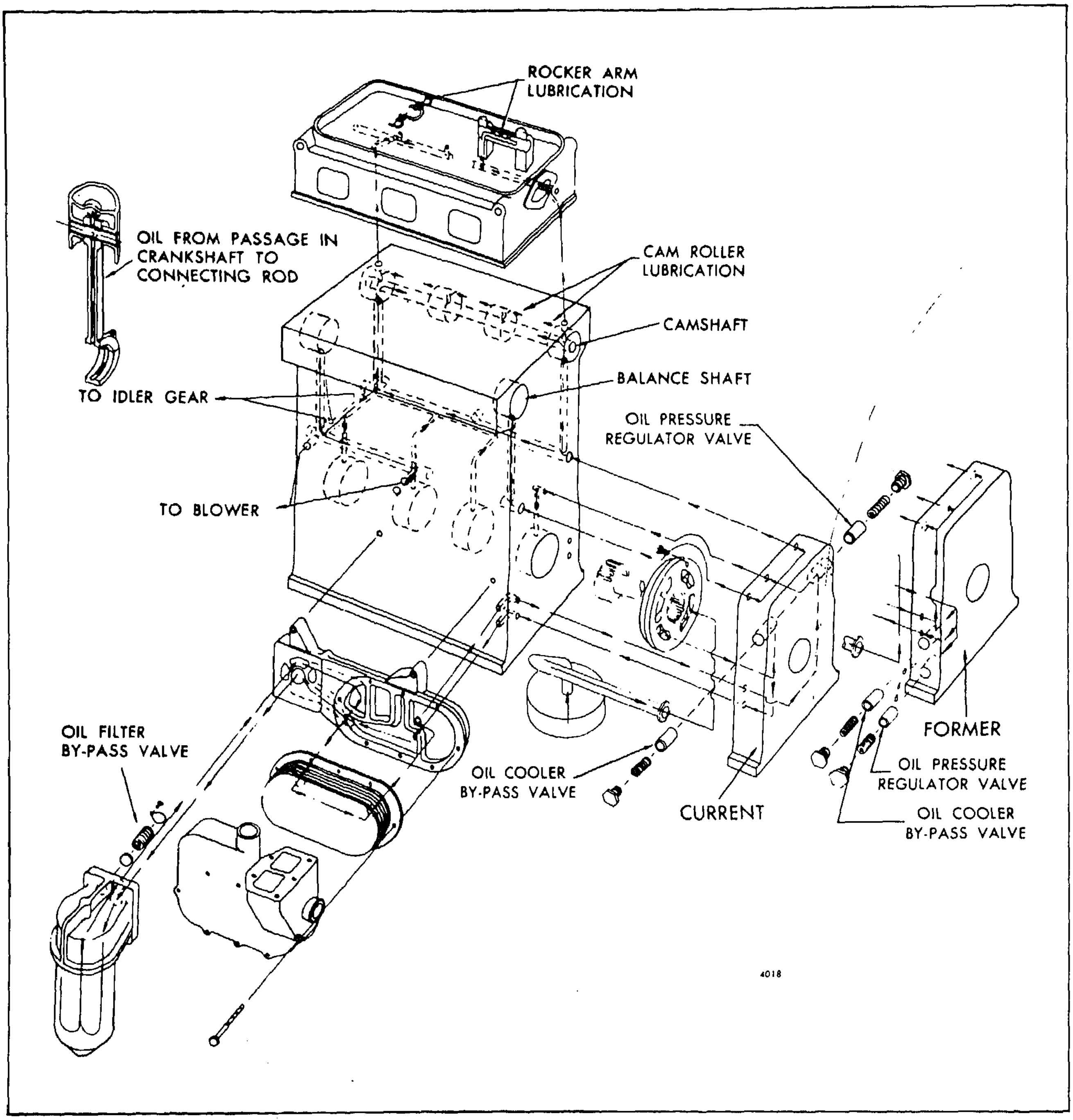


Fig. 1 - Schematic Diagram of Typical In-Line Engine Lubrication System

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located in the lower front engine cover. The regulator valve, located in the pump outlet passage, opens at 51 psi on In-line engines and returns excess oil directly to the crankcase.

Lubricating Oil Distribution

Oil from the oil cooler on the In-line engine is directed to the lower engine front cover and then to a longitudinal main oil gallery in the cylinder block. As shown in Fig. 1, this gallery distributes the oil, under pressure, to the main bearings and to a horizontal transverse passage at one end of the block and to vertical passages at each corner of the block which provide lubrication for the balance shaft and camshaft bearings. The camshaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. All of the camshaft bearings incorporate small slots through which lubricating oil is directed at the cam follower rollers.

Oil for lubricating the connecting rod bearings, piston pins, and for cooling the piston head is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the bearings of the camshafts, balance shaft (In-line engine).

Drilled oil passages on the camshaft side of the cylinder head (Fig . 1 are supplied with oil from the bores located at each end of the cylinder block. Oil from these drilled passages enters the drilled rocker shaft brackets at the lower ends of the drilled bolts and lubricates the rocker arm bearings and push rod clevis bearings.

Excess oil from the rocker arms lubricates the lower ends of the push rods and cam followers, then drains to cam pockets in the top of the cylinder block, from which the cams are lubricated. When these pockets are filled, the oil overflows through holes at each end of the cylinder block and then through the flywheel housing and front cover to the crankcase.

The blower bearings are pressure lubricated by oil from drilled passages in the cylinder block which connect matching passages in the blower end plates which, in turn, lead to the bearings. On current engines, lubricating oil is supplied directly to the front and rear right bank camshaft end bearings and supplies oil to the blower bearings. On former engines, the blower bearings received lubrication indirectly via the right rear camshaft end bearing only. Excess oil returns to the crankcase via drain holes in the blower end plates which lead to corresponding drain holes in the cylinder block (In-line engines).

One tapped oil pressure take-off hole is provided in the lower engine front cover on some In-line engines.

In addition, tapped oil holes in the cylinder block, on the side opposite the blower, are also provided as follows:

three holes when the blower is on the right side of the engine.

Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol antifreeze solution or other soluble material, refer to Section 5 for the recommended cleaning procedure.

LUBRICATING OIL PUMP

IN-LINE ENGINES

The lubricating oil pump, assembled to the inside of the lower engine front cover as illustrated in Fig. 1, is of the rotor type in which the inner rotor is driven by a gear pressed on the front end of the crankshaft. The outer rotor is driven by the inner rotor. The bore in the pump body, in which the outer rotor revolves, is eccentric to the crankshaft and inner rotor. Since the outer rotor has nine cavities and the inner rotor has eight lobes, the outer rotor revolves at eight-ninths crankshaft speed. Only one lobe of the inner rotor is in full engagement with the cavity of the outer rotor at any given time, so the former can revolve inside the latter without interference.

By rotating the pump 180 °, it can be used for either a right-hand or left-hand rotation engine.

Operation

As the rotors revolve, a vacuum is formed on the inlet side of the pump and oil is drawn from the crankcase, through the oil pump inlet pipe and a passage in the front cover, to the inlet port and then into the rotor compartment of the pump. Oil drawn into the cavities between the inner and outer rotors on the inlet side of the pump is then forced out under pressure through the discharge port into a passage in the front cover, which leads to the lubricating oil filter and cooler, and is then distributed throughout the engine.

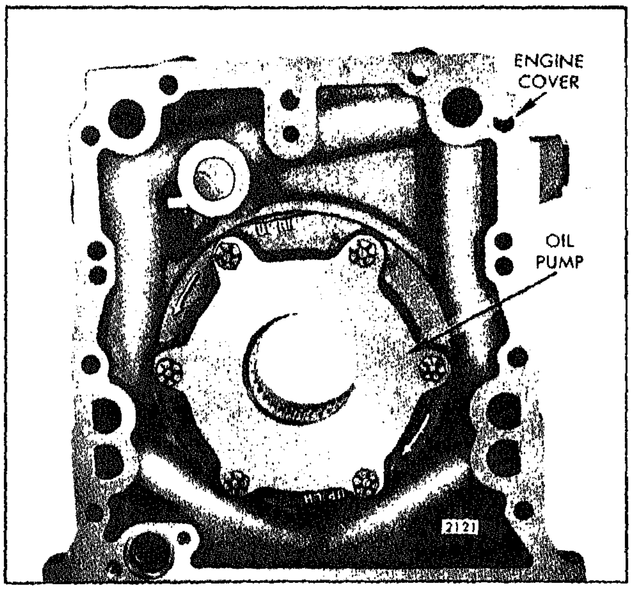


Fig. 1 - Typical Right-Hand Rotation Lubricating Oil Pump Mounting

If a check of the lubrication system indicates improper operation of the oil pump, remove and disassemble it as outlined below.

Remove Oil Pump

1. Drain the oil from the engine.

2. Remove the crankshaft pulley, fan pulley, support bracket and any other accessories attached to the front cover.

3. Remove the oil pan.

4. Refer to Fig. 2 and remove the four bolts which attach the oil pump inlet pipe and screen assembly to the main bearing cap and engine front cover or oil pump inlet elbow. Slide the flange and the seal ring on the inlet pipe and remove the pipe and screen as an assembly. Remove the oil pump inlet elbow (if used) and gasket from the engine front cover.

5. Remove the lower engine front cover.

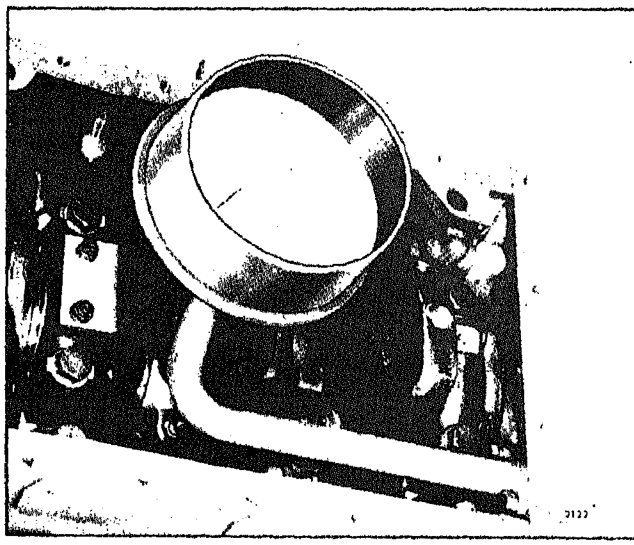


Fig. 2 - Typical Oil Pump Inlet Pipe and Screen Mounting

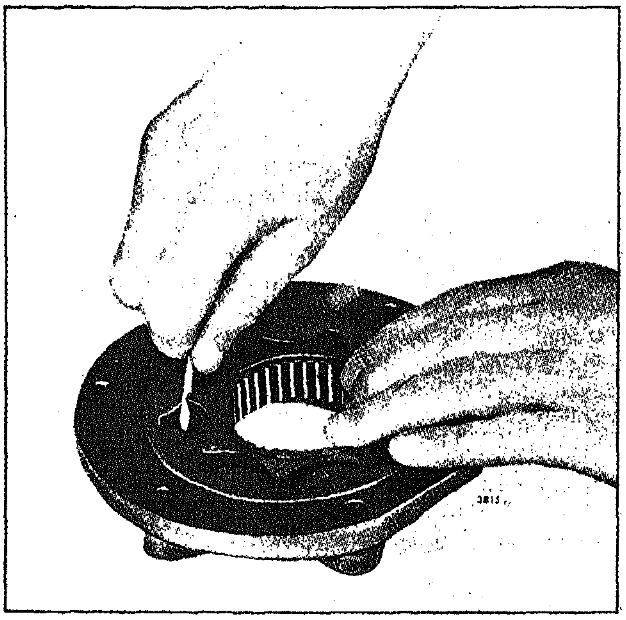


Fig. 3 - Measuring Rotor Clearance

6. Remove the six bolts and lock washers (if used) which attach the pump assembly to the engine front cover (Fig. 1) and withdraw the pump assembly from the cover.

Disassemble Oil Pump

If the oil pump is to be disassembled for inspection or reconditioning, proceed as follows:

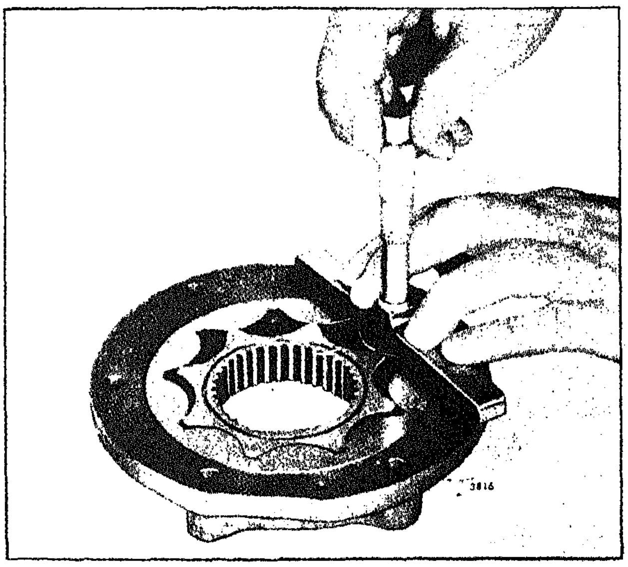


Fig. 4 - Measuring Clearance from Face of Pump Body to Side of Rotor

1. Refer to Fig. 5 and remove the two drive screws holding the pump cover plate to the pump body. Withdraw the cover plate from the pump body.

2. Remove the inner and outer rotors from the pump housing.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

The greatest amount of wear in the oil pump is imposed on the lobes of the inner and outer rotors.

This wear may be kept to a minimum by using clean oil. If dirt and sludge are allowed to accumulate in the lubricating system, excessive rotor wear may occur in a comparatively short period of time.

Inspect the lobes and faces of the pump rotors for scratches or burrs and the surfaces of the pump body and cover plate for scoring. Scratches or score marks may be removed with an emery stone.

Measure the clearance between the inner and outer rotors at each lobe (Fig. 3). The clearance should not be less than .004 " or more than .011 ". Measure the clearance from the face of the pump body to the side of the inner and outer rotor with a micrometer depth gage (Fig. 4). The clearance should be not less than .001 " or more than .0035 ".

Inspect the splines of the inner rotor and the oil pump drive gear. If the splines are excessively worn, replace the parts. The rotors are serviced as matched sets, therefore, if one rotor needs replacing, replace both rotors.

Remove the oil inlet screen from the oil inlet pipe and clean both the screen and the pipe with fuel oil and dry them with compressed air. Replace the inlet pipe flange seal ring with a new seal ring if necessary.

Assemble Oil Pump

After the oil pump parts have been cleaned and inspected, refer to Fig. 5 or 6 and assemble the pump as follows:

1. Lubricate the oil pump outer rotor with engine oil and place it in the pump body.

2. Lubricate the oil pump inner rotor with engine oil and place it inside of the outer rotor.

3. Place the cover plate on the pump body and align the drive screw and bolt holes with the holes in the

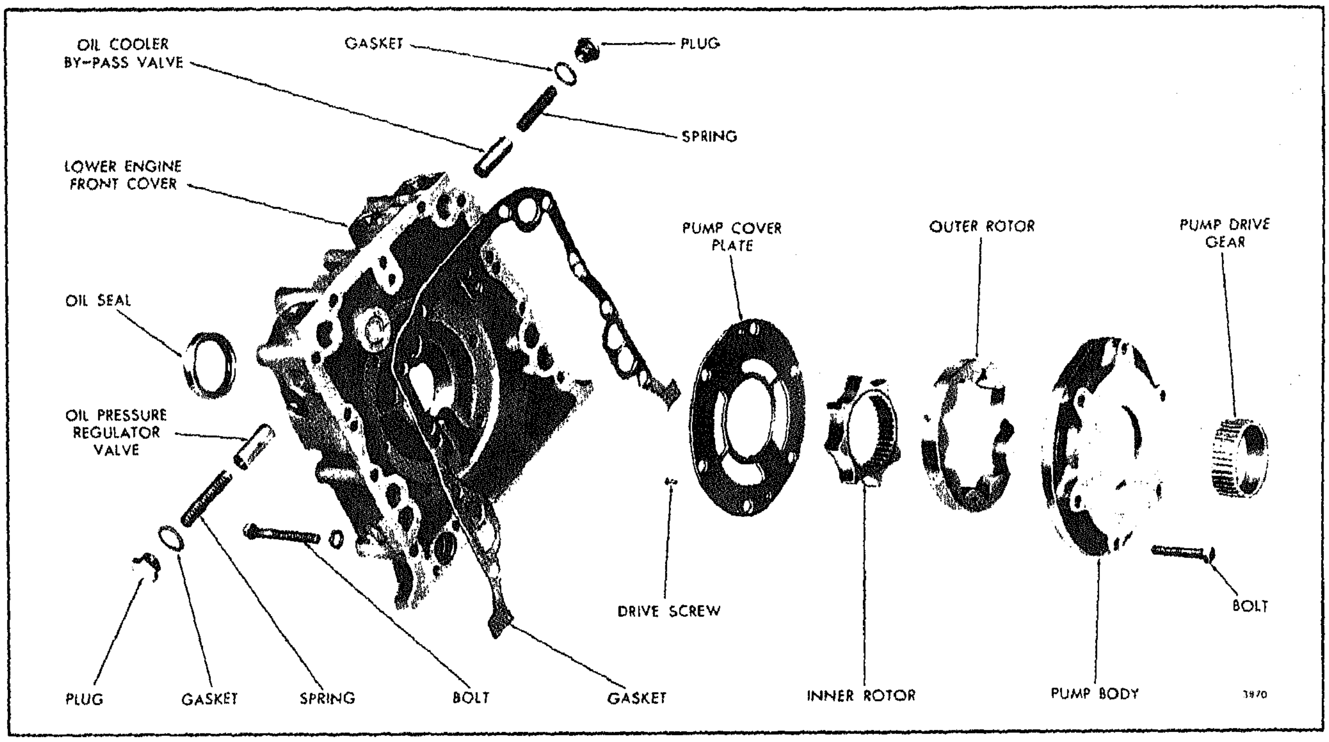


Fig. 5 · Lubricating Oil Pump Details and Relative Location of Parts (Current)

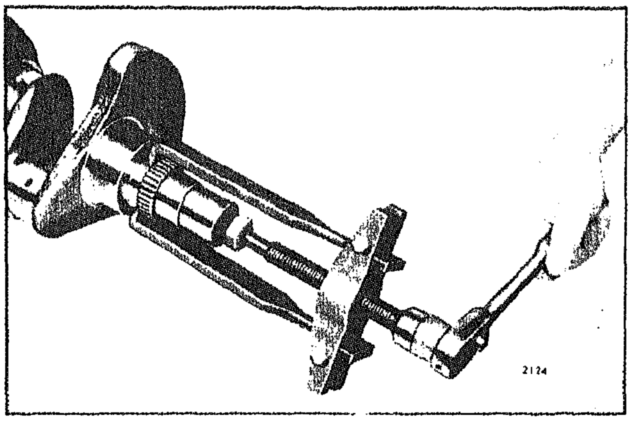


Fig. 7 · Removing Oil Pump Drive Gear

pump body. Since the holes are offset, the cover plate can be installed in only one position.

4. Install two new drive screws to hold the assembly together.

Remove Pump Drive Gear From Crankshaft

With the lower engine front cover and the lubricating oil pump removed from the engine, the oil pump drive gear may, if necessary, be removed from the end of the crankshaft as follows:

1. Thread the crankshaft pulley retaining bolt in the end of the crankshaft (Fig. 7).

2. Attach the jaws of a suitable gear puller behind the gear and locate the end of the puller screw in the center of the pulley retaining bolt.

3. Turn the puller screw clockwise to remove the gear from the crankshaft.

Install Pump Drive Gear on Crankshaft

1. Lubricate the inside diameter of a new oil pump drive gear with engine oil. Then start the gear straight on the crankshaft. Re-installation of a used gear is not recommended.

2. Position the drive gear installer J 8968-01 over the end of the crankshaft and against the drive gear and force the gear in place as shown in Fig. 8. When the end of the bore in the tool contacts the end of the crankshaft, the drive gear is correctly positioned.

3. It is important that the press fit of the drive gear to ·kshaft be checked to be sure that the gear does · crankshaft. It is recommended the press

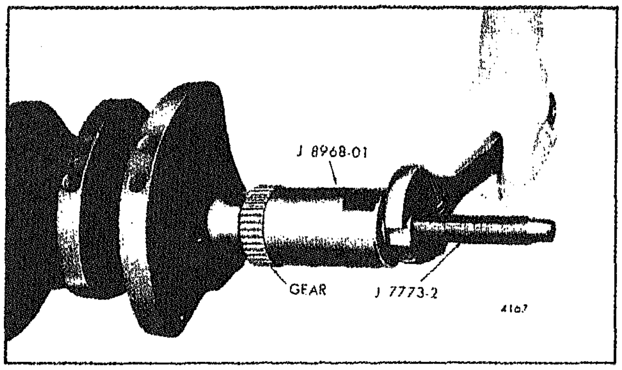


Fig. 8 · Installing Oil Pump Drive Gear

fit (slip torque) be checked with tool J 23126. On In-line engines, the drive gear should not slip on the crankshaft at 100 lb-ft torque.

CAUTION: Do not exceed these torques. If the gear slips on the shaft, it is suggested that another oil pump drive gear be installed.

Install Oil Pump

1. The markings on the pump body indicate the installation as pertaining to left or right-hand crankshaft rotation. Be sure that the letters "UP R.H." (right-hand rotation engine) on the pump body are at the top (Fig. 1).

2. Insert the six bolts with lock washers (if used) through the pump body and thread them into the engine front cover. Tighten the bolts to 13-17 lb-ft torque.

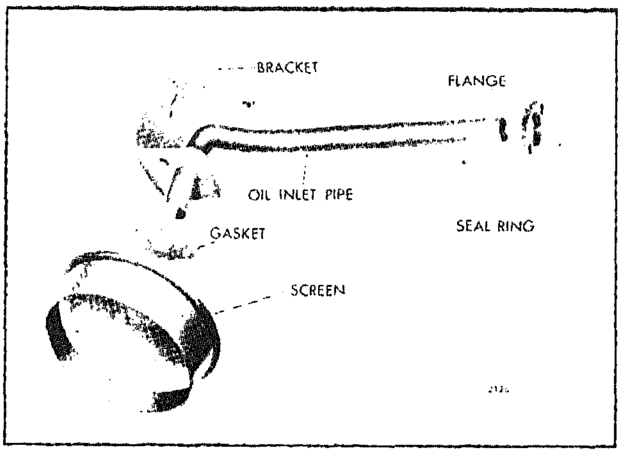


Fig. 9 · Oil Pump Inlet Pipe and Screen Details and Relative Location of Parts (In-Line Engine)

3. Install the lower engine front cover and pump assembly on the engine as outlined in Section 1.3.5.

4. Attach the oil inlet screen to the oil inlet pipe support with two bolts and lock washers (Fig. 9).

6. Place the oil pump inlet pipe and screen assembly in position and fasten the support to the main bearing cap with the two bolts and lock washers.

7. Slide the inlet pipe flange and seal ring against the engine front cover and secure them with the two bolts and lock washers.

CAUTION: On In-line engines, the oil pump inlet tube and water by-pass tube seals are the same size but of different material. *Be sure that the correct seal is used.* A new oil pump inlet tube seal may be identified by its white stripe.

8. Install the oil pan and refill the crankcase to the proper level.

9. Install the crankshaft pulley, fan pulley, support bracket and any other accessories that were attached to the front cover.

LUBRICATING OIL PRESSURE REGULATOR

IN-LINE ENGINES

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of oil temperature, by a pressure regulator valve installed in the engine lower front cover as shown in Fig . 1.

The regulator assembly consists of a hollow piston type valve, a spring, gasket and plug. The valve is located in an oil gallery within the lower front cover and is held tight against a counterbored valve seat by the valve spring and plug. When the oil pressure exceeds a given value as shown in the following chart, the valve is forced from its seat and the lubricating oil is by-passed into the engine oil pan.

Engine	Front Cover	Valve Opening Pressure (psi)
In-line		
	Current	51

Under normal conditions, the pressure regulator valve should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

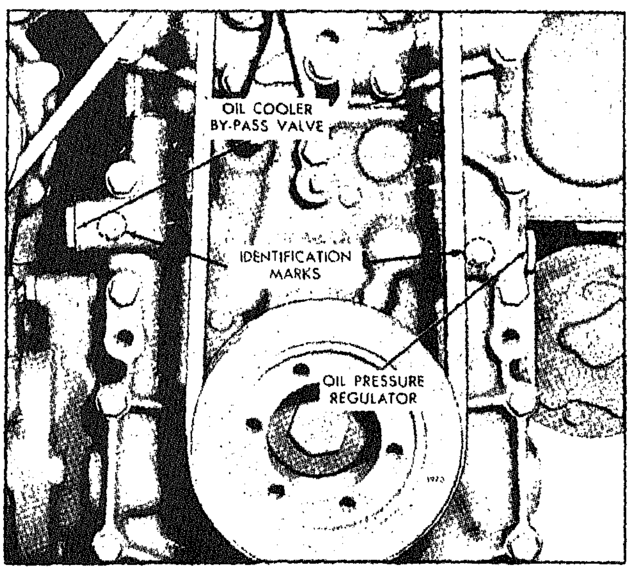


Fig. 1 - Location of Current Oil Pressure Regulator Valve -- In-line Engine Shown

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

1. Remove the plug and washer from the engine lower front cover.

2. Withdraw the spring and the valve from the cover.

Inspection

Clean all of the regulator parts in fuel oil and dry them with compressed air. Then inspect the parts for wear or damage.

The regulator valve must move freely in the valve bore. If the valve is scored and cannot be cleaned up with crocus cloth, it must be replaced.

Replace a fractured or pitted spring.

Install Oil Pressure Regulator

1. Apply clean engine oil to the outer surface of the valve and slide it into the opening in the engine lower front cover (closed end first).

2. Install a new copper gasket on the plug.

3. While compressing the spring, start the plug in the side of the cover; then tighten the plug.

LUBRICATING OIL COOLER

Engine oil coolers are provided for all engines.

The oil cooler is mounted on the side of the cylinder block at the lower front corner.

To assure engine lubrication should the oil cooler become plugged, a by-pass valve located near the top of the lower engine front cover by-passes oil from the oil pump discharge port directly to the oil galleries in the cylinder block. The by-pass valve opens at approximately 52 psi (current In-line engines).

The valve components are the same as and serviced in the same manner as the oil pressure regulator valve in Section 4.1.1.

Cooling water circulated through the oil cooler completely surrounds the oil cooler core. Therefore, whenever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing on an In-line engine is attached to an oil cooler adaptor which, in turn, is attached to the cylinder block. The flow of oil is from the oil pump through a passage in the oil cooler adaptor to the full flow oil filter, which is also mounted on the oil cooler adaptor, and then through the oil cooler core and the cylinder block oil galleries.

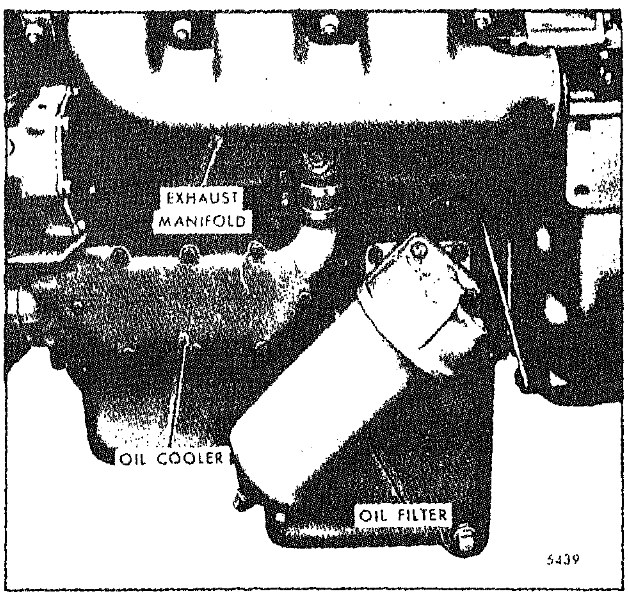


Fig. 1 - Typical Oil Cooler Mounting (6V-53 Engine Shown)

Remove Oil Cooler Core

1. Drain the cooling system by opening the drain cock at the bottom of the oil cooler housing.

2. Remove any accessories or other equipment necessary to provide access to the cooler.

3. On In-Line engines, loosen and slide the clamps and hose back on the water inlet elbow on the cylinder block.

4. Loosen and slide the clamps and hose back on the tube leading from the thermostat to the water pump.

5. Remove the bolts and lock washers which attach the water pump to the oil cooler housing.

6. Matchmark the end of the oil cooler housing, cooler core and adaptor with a punch or file so they can be reinstalled in the same position.

7. Remove the bolts and lock washers which attach the oil cooler housing to the adaptor or cylinder block and remove the housing and core as an assembly. Be careful when withdrawing the assembly not to drop or damage the cooler core.

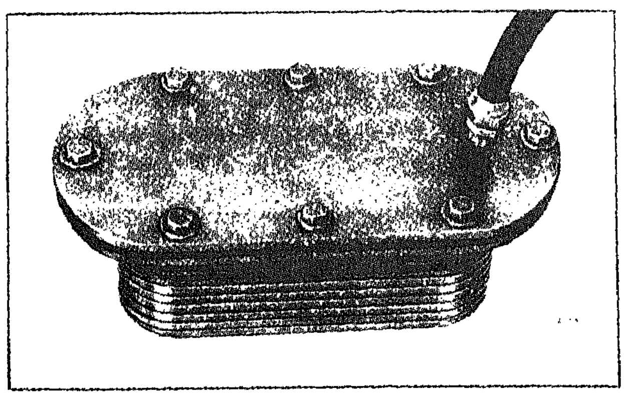


Fig. 2 - Preparing Oil Cooler Core for Pressure Test

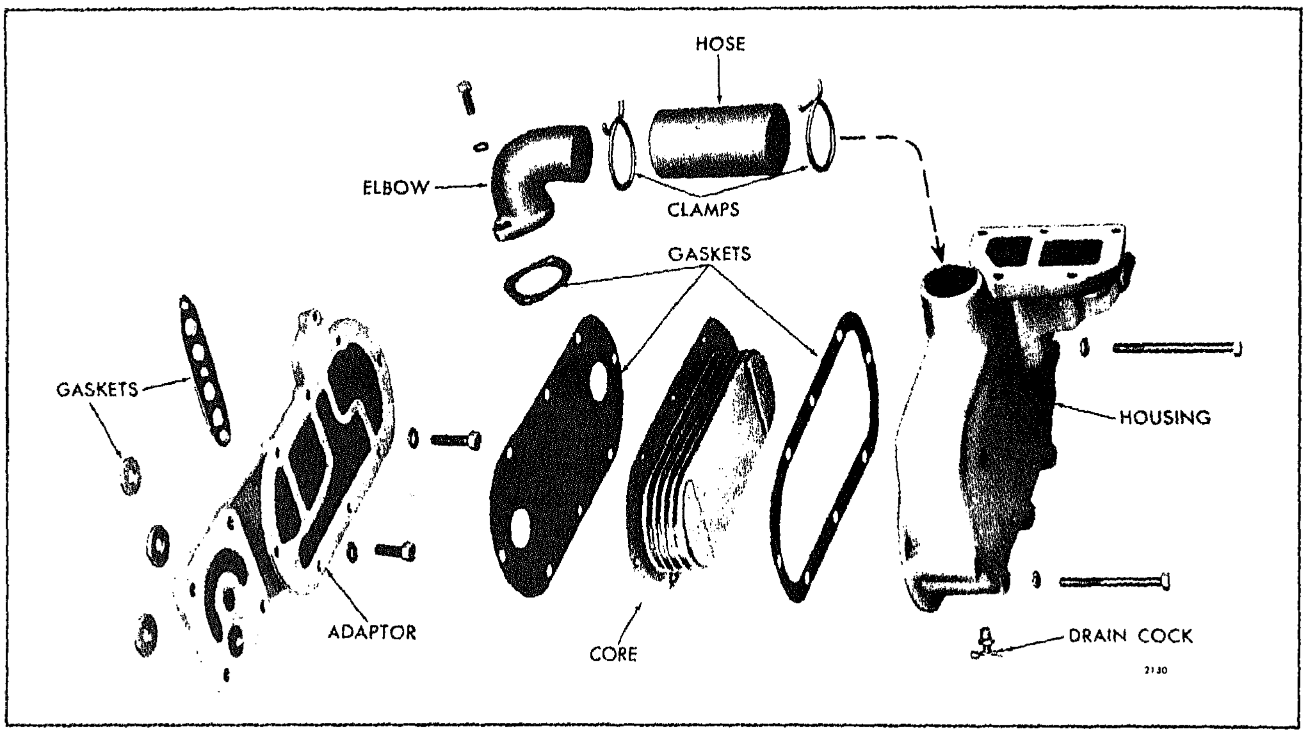


Fig. 3 - Oil Cooler Details and Relative Location of Parts (In-Line Engine)

8. If the adaptor (In-line engine) is to be removed, the oil filter must first be removed. Then remove the bolts and lock washers which attach the adaptor to the cylinder block. Withdraw the adaptor and gaskets.

9. Remove all traces of gasket material from the cylinder block and the oil cooler components.

Clean Oil Cooler Core

1. *Clean oil side of Core* - Remove the core from the oil cooler. Circulate a solution of trichloroethylene through the core passages with a force pump to remove the carbon and sludge.

> **CAUTION:** This operation should be done in the open or in a well ventilated room when trichloroethylene or other toxic chemicals are used for cleaning.

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the core and flush thoroughly with clean, hot water.

2. *Clean water side of Cooler* - After cleaning the oil side of the core, immerse it in the following solution: Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one third muriatic acid and two-thirds water. The cleaning action is evidenced by bubbling and foaming.

Watch the process carefully and, when bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean, hot water. After cleaning, dip the core in light oil.

> **NOTE:** Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. Replace the oil cooler core.

Pressure Check Oil Cooler Core

After the oil cooler core has been cleaned, check for leaks as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to assure a tight seal. Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the core (Fig. 2).

2. Attach an air hose, apply approximately 75-150 psi air pressure and submerge the oil cooler core and plate assembly in a container of water heated to 180 °F. Any leaks will be indicated by air bubbles in the water. If leaks are indicated, replace the core.

> **CAUTION:** When making this pressure test be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.

3. After the pressure check is completed, remove the plate and air hose from the cooler core, then dry the core with compressed air.

> **NOTE:** In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent serious damage (refer to Section 5).

Install Oil Cooler Core

1. If the oil cooler adaptor (In-Line engines) was removed from the cylinder block, remove the old gasket material from the bosses where the adaptor sets against the block. Affix new adaptor gaskets (Fig. 3), then secure the adaptor to the cylinder block with five bolts and lock washers.

2. Clean the old gasket material from both faces of the core flange and affix new gaskets to the inner and outer faces (Fig . 3). Insert the core into the cooler housing.

> **NOTE:** The inlet and outlet openings in the oil cooler core are stamped "IN" and "OUT". It is very important that the core be installed in the correct position to prevent any possibility of foreign particles and sludge, which may not have been removed in cleaning the fins of the core, entering and cirulating through the engine.

3. Align the matchmarks previously placed on the core and housing and install the oil cooler core in the oil cooler housing.

4. With the matchmarks in alignment, place the oil cooler housing and core against the oil cooler adaptor (In-Line engines).

Tighten the bolts to 13-17 lb-ft torque.

5. Slide the hose and clamps in position between the cylinder block water inlet elbow and the oil cooler. Secure the clamps in place.

6. Place a new gasket between the fresh water pump and the cooler housing and secure the pump to the cooler housing.

7. Position the hose and clamps in place between the water pump and the tube to the thermostat housing. Secure the clamps.

8. Install all of the accessories or equipment it was necessary to remove.

9. Reinstall the oil filter (In-Line engine).

10. Make sure the draincock in the bottom of the cooler housing is closed. Then fill the cooling system to the proper level.

OIL LEVEL DIPSTICK

A steel ribbon type oil level dipstick is mounted in an adaptor on the side of the engine (Fig. 1) to check the amount of oil in the engine oil pan. The dipstick has markings to indicate the *Low* and *Full* oil level.

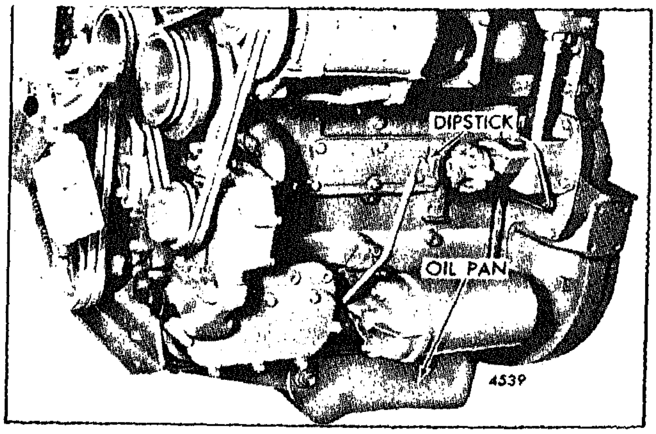


Fig. 1 - Typical Oil Dipstick Mounting

The engine should not be operated if the oil level is below the *Low* mark and no advantage is gained by having the oil quantity above the *Full* mark. Start and operate the engine for ten minutes to fill the oil filter, oil passages, etc., then stop the engine. After the engine has been stopped for a minimum of ten minutes, add oil as required to bring the oil level up to the *full* mark on the dipstick.

OIL PAN

The oil pan may be made of steel, cast iron or cast aluminum. A shallow or deep sump type oil pan is used, depending upon the particular engine application. A one-piece oil pan gasket is used with stamped steel pans.

Removing and Installing Oil Pan

On some engine applications, it may be possible to remove the oil pan without removing the engine. It is recommended that if the engine is to be taken out of the unit, the oil pan be left in place until the engine is removed.

The procedure for removing the oil pan without taking the engine out and after taking the engine out of the unit will vary. However, the following will generally apply.

1. Remove the drain plug and drain the engine lubricating oil.

2. Detach the oil pan; take precautions to avoid damaging the oil pump inlet pipe and screen.

   NOTE: Stamped oil pans used on some marine engines have a layer of lead or cadmium beneath the paint to protect the pans against the salt water atmosphere encountered in some marine applications. If this coating is scuffed or broken unknowingly, corrosion or electrolysis may result. Electrolysis in the form of small holes will eat through the pan at the scuffed area. Therefore, do not rest, slide or rock the engine on its oil pan when removing it. Every precaution should be taken before installation to prevent nicks and scratches on stamped marine oil pans. Also exercise care when performing engine repairs to avoid scratching the outer surface of the oil pan.

3. Remove the oil pan gasket completely.

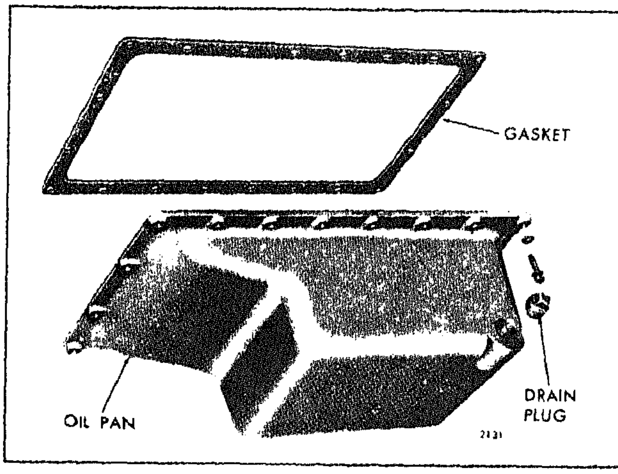


Fig. 1 · Typical Oil Pan

4. Clean the oil pan with a suitable solvent and dry it with compressed air.

5. Inspect a cast oil pan for porosity or cracks. Check a stamped oil pan for large dents or breaks in the metal which may necessitate its repair or replacement. Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.

6. When replacing the pan, use a new gasket and tighten the bolts evenly to avoid damaging the gasket or springing the pan.

8. Install and tighten the oil drain plug. Tighten the plug (with nylon washer) to 25-35 lb-ft torque. Replenish the lubricating oil supply and, after the engine is started, check for leaks.

VENTILATING SYSTEM

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartment by a continuous, pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the airbox past the piston rings. This air sweeps up through the engine and is drawn off through a crankcase breather.

In-line engines are equipped with a breather assembly attached to the valve rocker cover (Fig. 1) or a breather assembly mounted on the flywheel housing (Fig. 2).

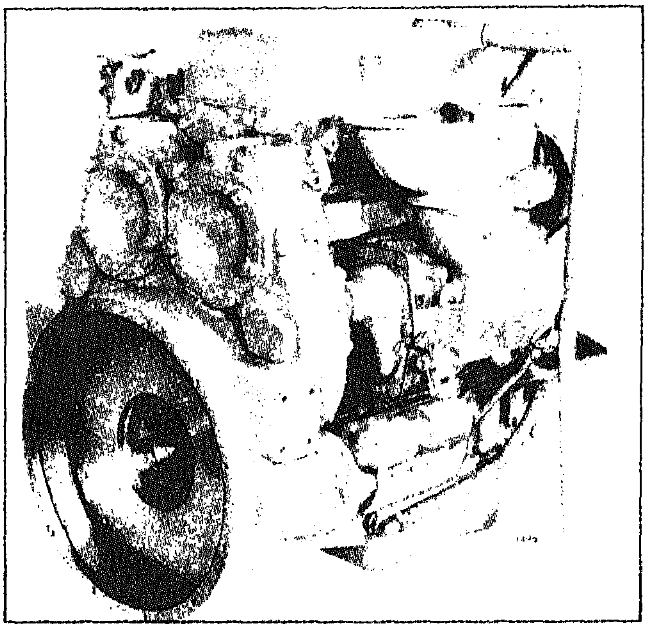


Fig. 1 - Typical Crankcase Breather Mounting (In-Line Engine)

Service

It is recommended that the breather tube be inspected and cleaned, if necessary, to eliminate the possibility of clogging. This can best be done by removing the tube from the engine, washing it with a suitable solvent and drying it with compressed air.

The wire mesh pad (element) in the breather

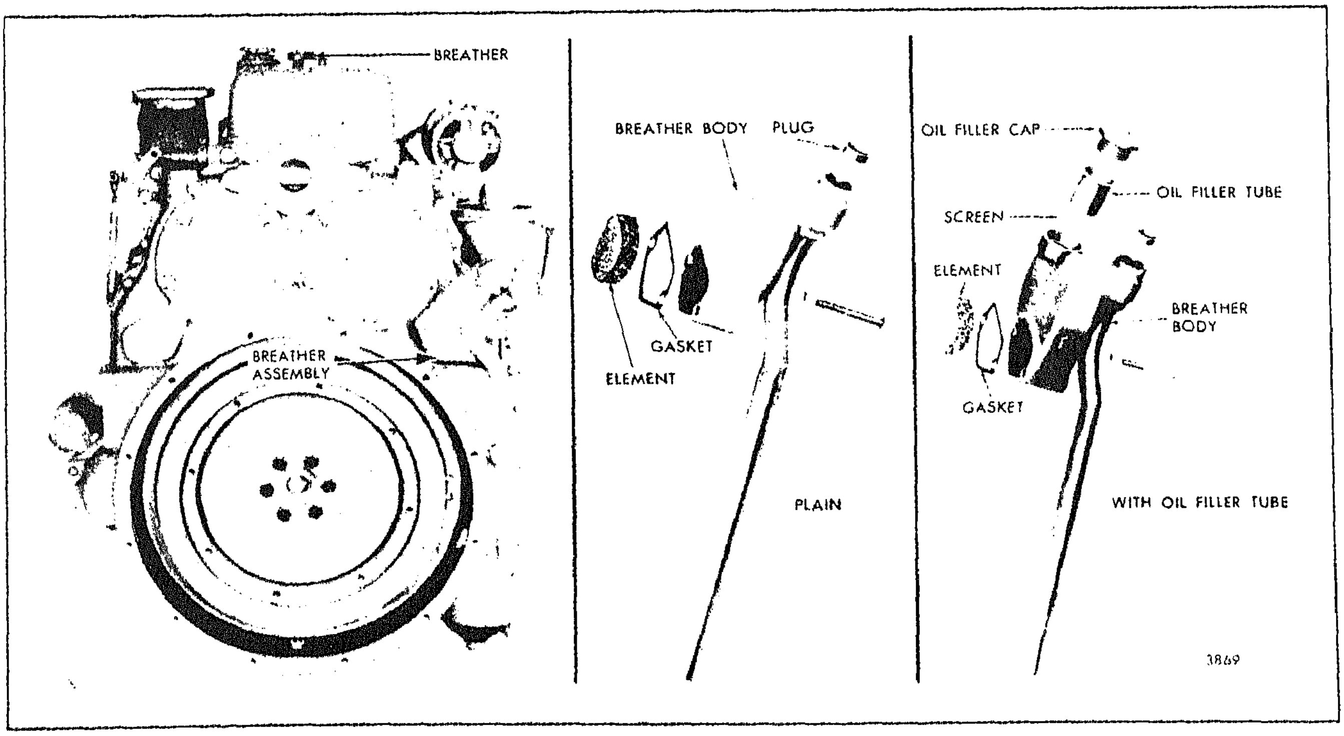


Fig. 2 - Crankcase Breather Mounting and Details (In-Line Engine)

assemblies should be cleaned if excessive crankcase pressure is observed.

If it is necessary to clean the element, remove the breather housing from the flywheel housing (In-line engines).

Wash the element in fuel oil and dry it with compressed air.

Reinstall the element in the breather housing, the upper front cover or the governor housing and/or the valve rocker cover and install them by reversing the procedure for removal.

SPECIFICATIONS - SERVICE TOOLS

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	TORQUE (lb-ft)	THREAD SIZE	TORQUE (lb-ft)
1/4 -20	7-9	9/16-12	90-100
1/4 -28	8-10	9/16-18	107-117
5/16-18	13-17	5/8 -11	137-147
5/16-24	15-19	5/8 -18	168-178
3/8 -16	30-35	3/4 -10	240-250
3/8 -24	35-39	3/4 -16	290-300
7/16-14	46-50	7/8 - 9	410-420
7/16-20	57-61	7/8 -14	475-485
1/2 -13	71-75	1 - 8	580-590
1/2 -20	83-93	1 -14	685-695

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	TORQUE (lb-ft)
Oil filter center stud	40-50
Oil pan drain plug (Nylon washer) 18mm	25-35

SERVICE TOOLS

TOOL NAME	TOOL NO.
Crankshaft and oil pump gear puller	J 3051
Oil pump drive gear installer	J 8968-01
Oil pump drive gear adaptor	J 23126
Two-arm steel grip puller	J 8174

SECTION 5

COOLING SYSTEM

CONTENTS

WATER PUMP

A centrifugal-type water pump (Fig. 1) is mounted on top of the engine oil cooler housing as shown in Fig. 2. It circulates the coolant through the oil cooler, cylinder block, cylinder head(s) and radiator.

The pump is belt driven by either the camshaft or balance shaft (In-line engines).

An impeller is pressed onto one end of the water pump shaft, and a water pump drive pulley is pressed onto the opposite end. The pump shaft is supported on a sealed double-row combination radial and thrust ball bearing. Coolant is prevented from creeping along the shaft toward the bearing by a seal. The shaft and bearing constitute an assembly, and are serviced as such, since the shaft serves as the inner race of the ball bearing.

The sealed water pump shaft ball bearing is filled with lubricant when assembled. No further lubrication is required.

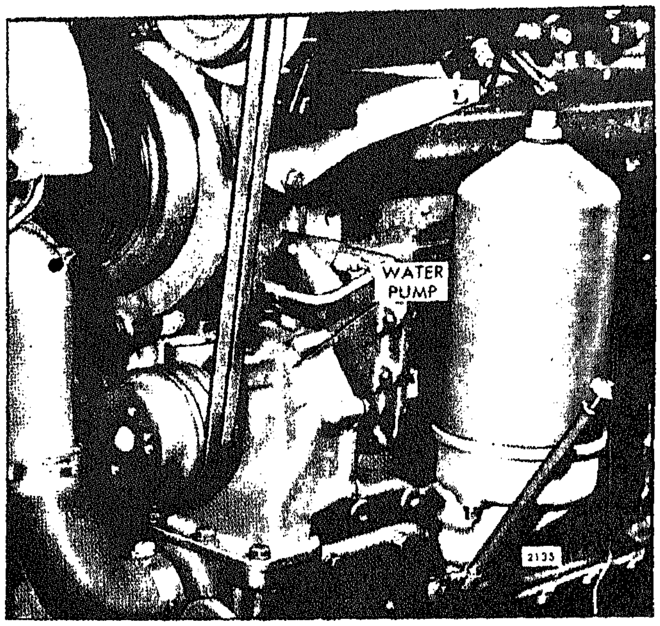


Fig. 2 - Typical Water Pump Mounting

NOTE: An idler pulley is used on some engines to adjust the water pump drive belt tension.

Remove Water Pump

1. Remove the radiator cap, open the block and radiator drain cocks, and drain the cooling system.

2. Loosen and remove the water pump belts.

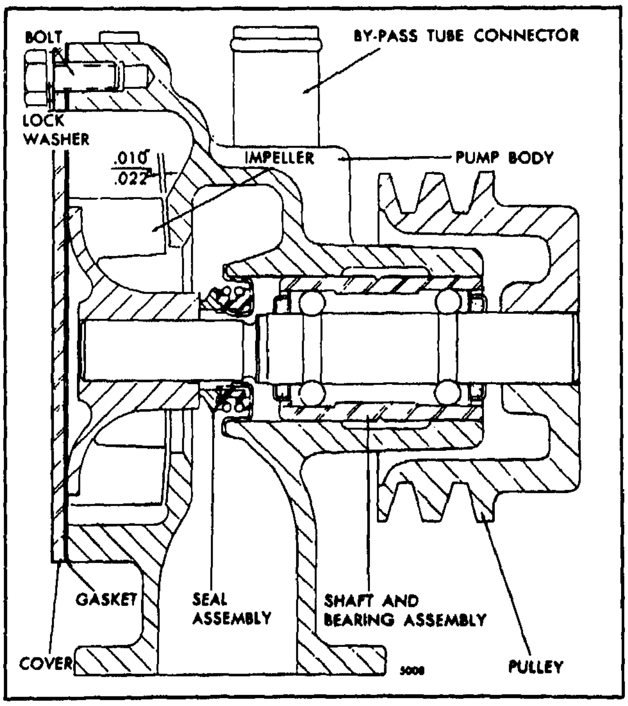


Fig. 1 - Water Pump Assembly

3. Loosen the hose clamps and slide the hose up on the water by-pass tube.

4. Remove the five bolts securing the water pump to the oil cooler housing and take off the pump.

Disassemble Pump

1. Note the position of the pulley on the shaft so that the pulley can be reinstalled in the same position when the pump is reassembled. Remove the water pump pulley as shown in Fig. 3.

2. Remove the pump cover and discard the gasket.

3. Press the shaft and bearing assembly, seal, and impeller out of the pump body as an assembly, by applying pressure on the bearing outer race with remover J 1930.

CAUTION: The bearing will be damaged if the pump is disassembled by pressing on the end of the pump shaft.

4. Press the end of the shaft out of the impeller as shown in Fig. 4, using plates J 8329 and holder J 358-1.

5. Remove the seal assembly from the pump shaft and discard it.

Inspection

Wash all of the pump parts, except the bearing and shaft assembly, in clean fuel oil and dry them with compressed air.

> **NOTE:** A permanently sealed and lubricated bearing is used in the bearing and shaft assembly and should not be washed. Wipe the bearing and shaft assembly with a clean lintless cloth.

Examine the impeller for damage and excessive wear on the impeller face which contacts the seal. Replace the impeller if it is worn or damaged.

Discard the bearing if it has a general feeling of roughness, is tight or has indications of damage.

Assemble Pump

1. Use installer J 1930 to apply pressure to the outer race of the bearing as shown in Fig. 5 and press the shaft and bearing assembly into the pump body until the outer race of the bearing is flush with the outer face of the body.

> **CAUTION:** The bearing will be damaged if the bearing and shaft assembly is installed by applying pressure on the end of the shaft.

2. Lightly coat the outside diameter of the new seal with sealing compound. Then, with the face of the body and the bearing outer race supported, install the seal by applying pressure on the seal outer flange only, until the flange contacts the body (Fig. 1). Wipe the face of the seal with a chamois to remove all dirt and metal particles.

3. Support the pulley end of the shaft on the bed of an arbor press and press the impeller on the shaft until the impeller is flush with the large end of the body.

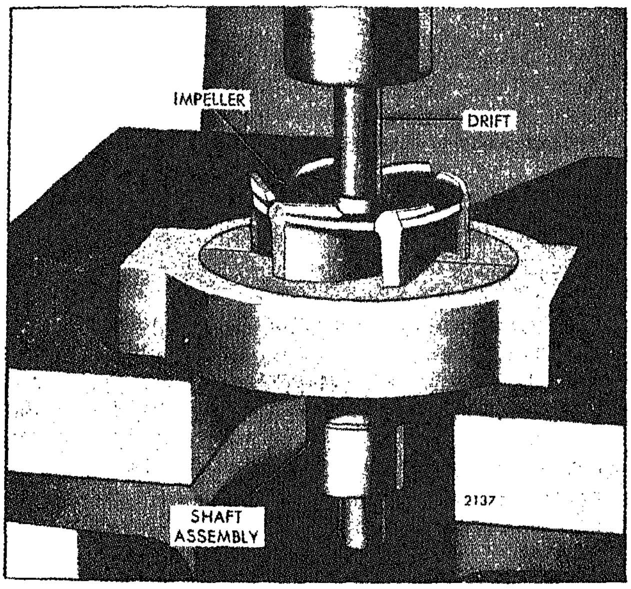
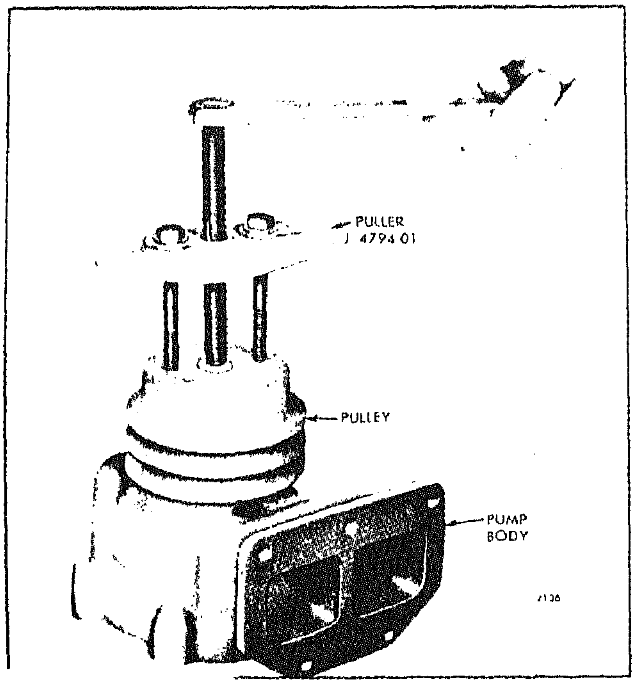


Fig. 4 - Removing Shaft from Impeller with Tools J 8329 and J 358-1



Removing Pulley

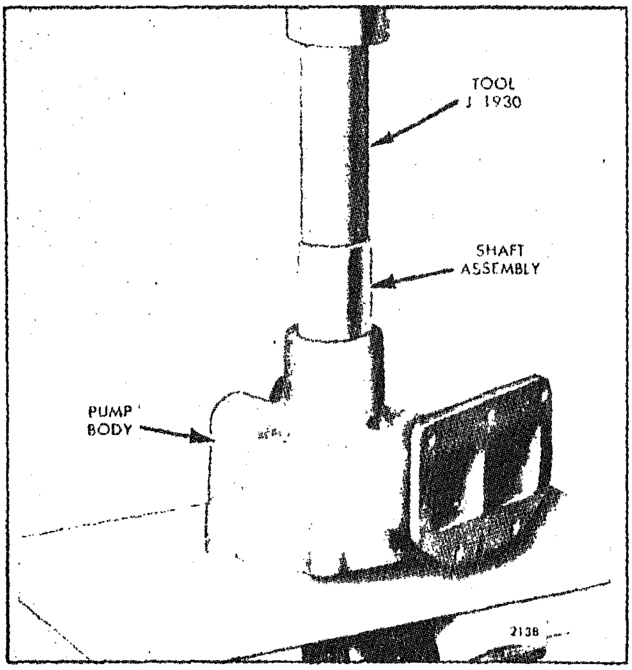


Fig. 5 - Pressing Shaft Assembly into Water Pump

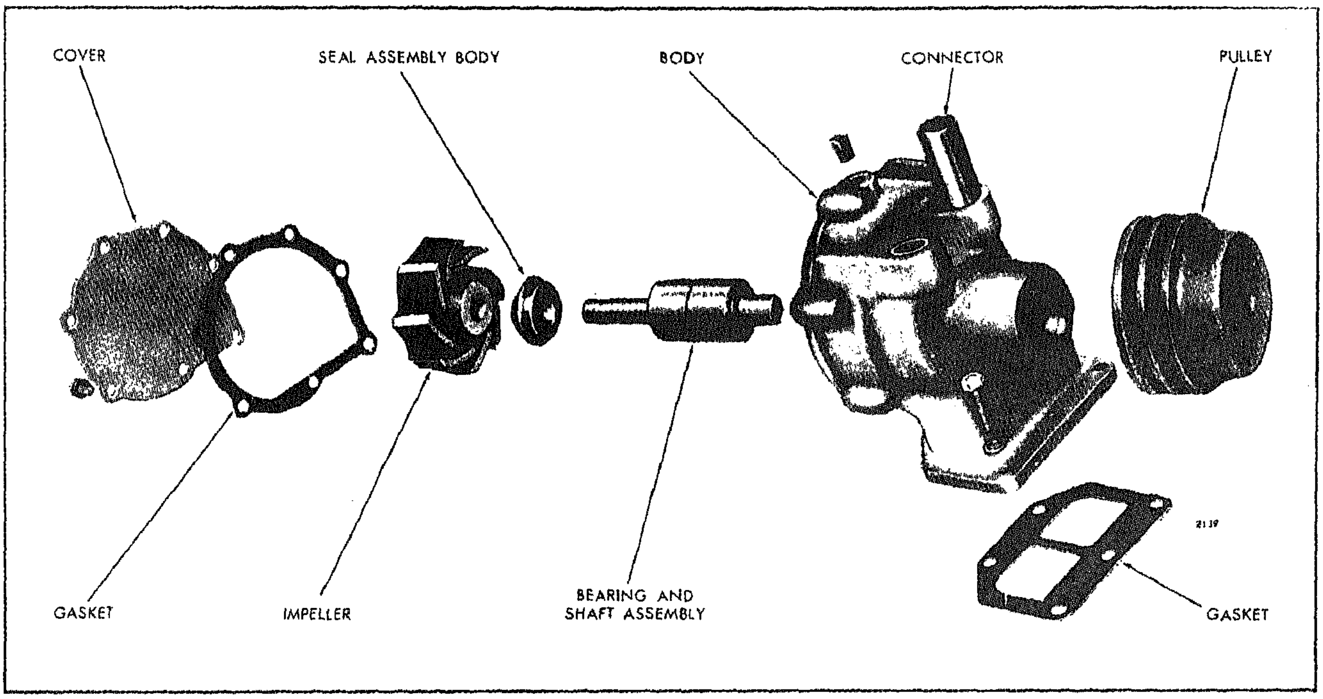


Fig. 6 · Fresh Water Pump Details and Relative Location of Parts

4. Place the pulley on the bed of an arbor press. Place a suitable rod between the ram of the press and the impeller end of the shaft, then press the shaft into the pulley until the pulley is in its original position on the shaft.

5. Install the cover and a new gasket on the pump body. Tighten the cover bolts to 6-7 lb-ft torque.

6. Run the pump dry at 1200 rpm for a minimum of 30 seconds, or as required, to assure satisfactory seating of the seal.

Install Water Pump

1. Affix a new gasket to the flange of the water pump body.

2. Secure the water pump to the oil cooler housing with the five bolts and lock washers.

3. Install the hose between the water pump and water by-pass tube and tighten the hose clamps.

4. Install and tighten the belts.

NOTE: An idler pulley is used on some engines to adjust the water pump drive belt tension.

5. Close all of the drain cocks and refill the cooling system.

6. Start the engine and check for leaks.

FRESH WATER PUMP WITH CERAMIC INSERT IN IMPELLER

Effective with engine serial number 3D-64888, current water pump assemblies used on Series 53 engines include an impeller and ceramic insert combination (Figs. 7 and 8). Disassembly and assembly of the current water pump is the same as the former water pump except as follows:

When removing the impeller protect the ceramic insert from damage at all times during pump overhaul. Always lay the impeller on the bench with the ceramic insert up to prevent damage to the insert.

Inspect the ceramic insert for cracks, scratches and bond to the impeller. If the insert is damaged, it may be replaced in the following manner:

1. Bake the used ceramic insert and impeller assembly at 500°F. for one hour to remove the ceramic insert. The ceramic insert can be removed easily from the counterbore while the adhesive is hot. Wire brush the impeller bond area to remove the old adhesive, oxide, scale, etc.

2. Wipe the impeller bond area and the grooved side of the new ceramic insert with a cloth soaked in a

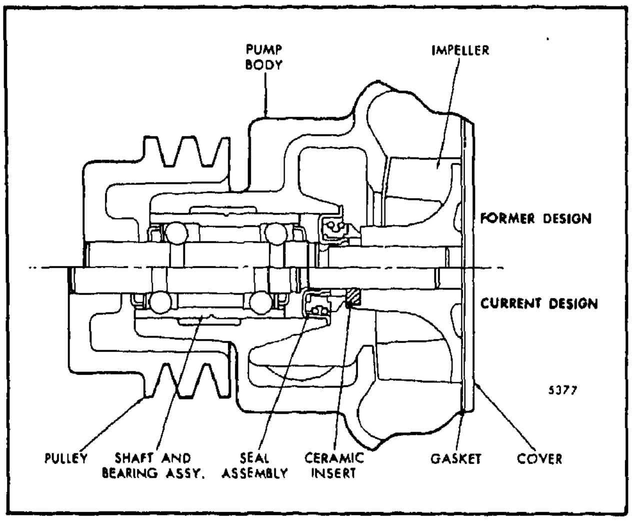


Fig. 7 - Comparison of Water Pumps

common solvent such as alcohol. Wipe clean with a dry cloth.

3. Place the adhesive washer in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler. Clamp the ceramic insert and impeller together with a 3/8" bolt and nut and two smooth 1/8" thick washers. Tighten the bolt to 10 lb-ft torque.

> **CAUTION:** Do not mar the polished surface of the ceramic insert.

4. Place the impeller assembly in a level position, with the ceramic insert up, in an oven preheated to 350°F. and bake it for one hour.

> **NOTE:** The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for inspection.

5. Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen the clamping bolt until the assembly cools. Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film.

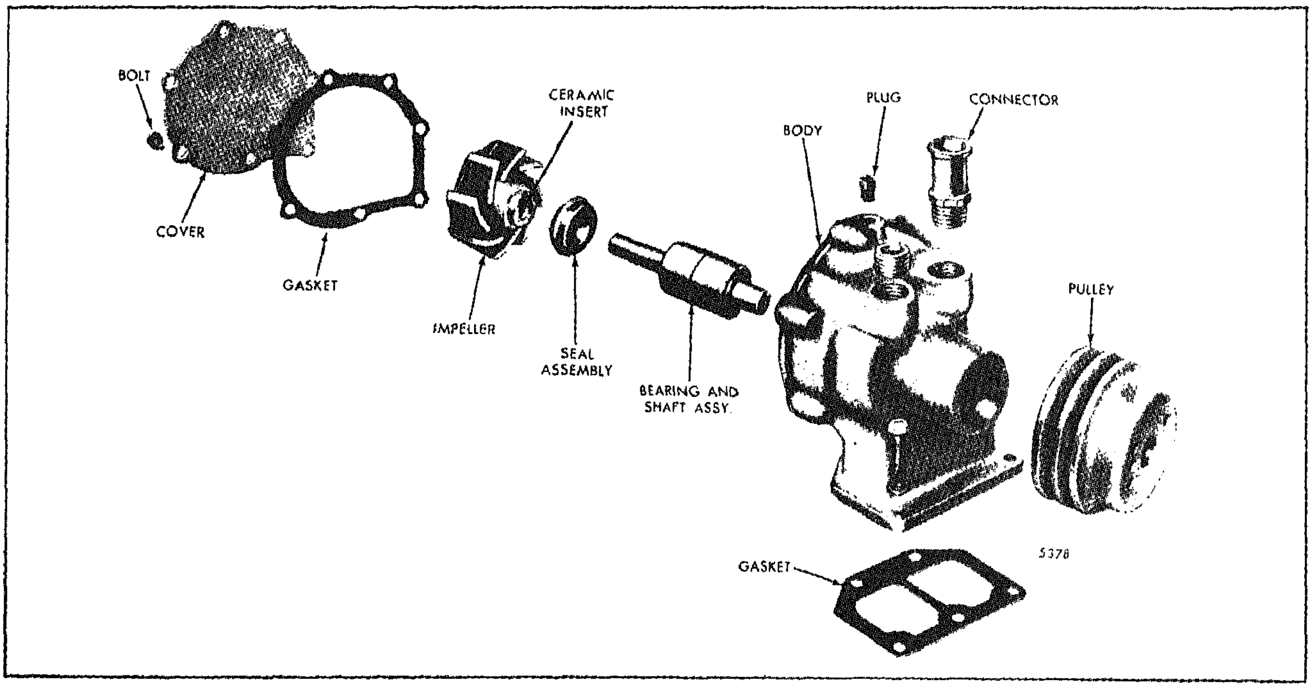


Fig. 8 - Details of Water Pump with Ceramic Seal

THERMOSTAT

The temperature of the In-line engine coolant is controlled by a single choke type thermostat located in a housing attached to the water outlet end of the cylinder head.

On the In-line engines, a by-pass tube is attached between the thermostat housing and the water pump.

At coolant temperatures below approximately 170°F., the thermostat valve remains closed and blocks the flow of coolant through the radiator or heat exchanger. During this period, the coolant circulates through the cylinder block and head and then back to the suction side of the pump via the by-pass tube. As the coolant temperature rises, the thermostat valve begins to open, restricting the by-pass system and permits the coolant to circulate through the radiator or heat exchanger.

With the valve fully opened in the in-line engine, a very small portion of the coolant will continue to circulate through the by-pass tube, while the major portion will pass through the radiator.

A properly operating thermostat is essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160°F - 185°F., remove and check the thermostat(s).

Remove Thermostat

1. Drain the cooling system to the necessary level by opening the drain valves.

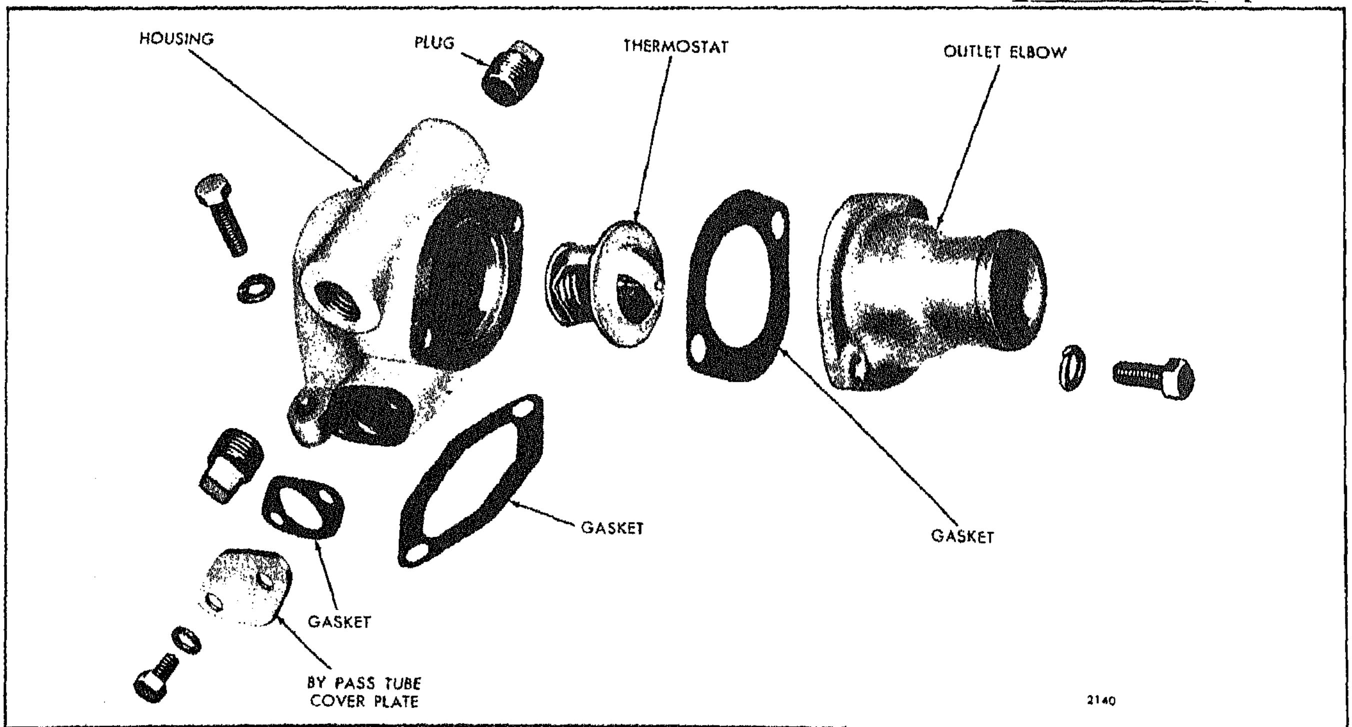


Fig. 2 - Thermostat Housing Details and Relative Location of Parts (In-Line Engine)

2. Remove the hose connections between the thermostat housing water outlet elbow and the radiator or heat exchanger.

3. Loosen the bolts and remove the water outlet elbow from the thermostat housing on the in-line engine (Fig. 2). Take out the thermostat.

Inspection

If the action of the thermostat has become impaired due to accumulated rust and corrosion from the engine coolant so that it remains closed, or only partially open, thereby restricting the flow of water, overheating of the engine will result. A thermostat which is stuck in a wide open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold operation will result in a build-up of carbon deposits on the pistons, rings and valves.

The operation of the thermostat may be checked by immersing it in a container of hot water (Fig. 4). Place a thermometer in the container, but do not allow
h the bottom. Agitate the water to maintain
emperature throughout the container. As the
eated, the thermostat valve should begin to

open when the temperature reaches 167° - 172°F. (In-line engine) or 174° - 176°F. (V-engine). The opening temperature is usually stamped on the thermostat. The thermostat should be fully open at approximately 190° - 192°F.

Clean the thermostat seating surface in the thermostat housing and base or the water outlet elbow.

Check the bleed hole in the thermostat housing to be sure it is open (Fig. 5).

Drill a 3/32" diameter hole in the thermostat housing used on in-line industrial engines built prior to serial number 3D-011 (refer to Fig. 6). This will provide a coolant drain hole for the by-pass cavity in the housing.

Install Thermostat

Refer to Fig . 2 and install the thermostat(s) as follows:

IN-LINE ENGINE:

1. Place a new gasket on the thermostat housing.

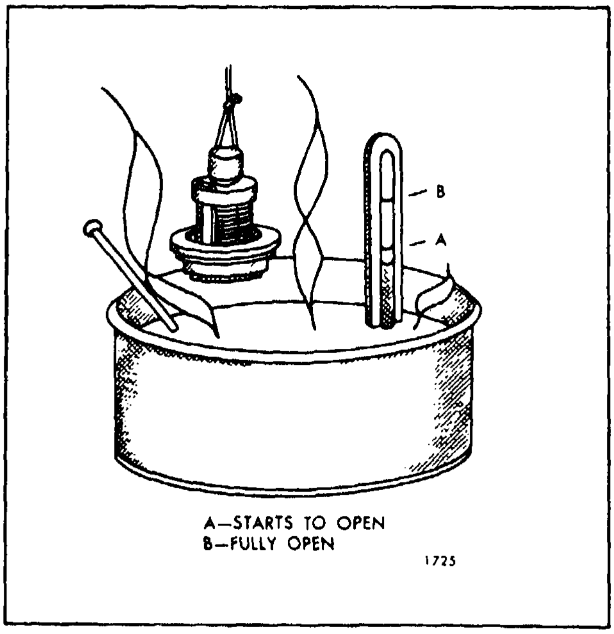


Fig. 4 · Method of Checking Thermostat Operation

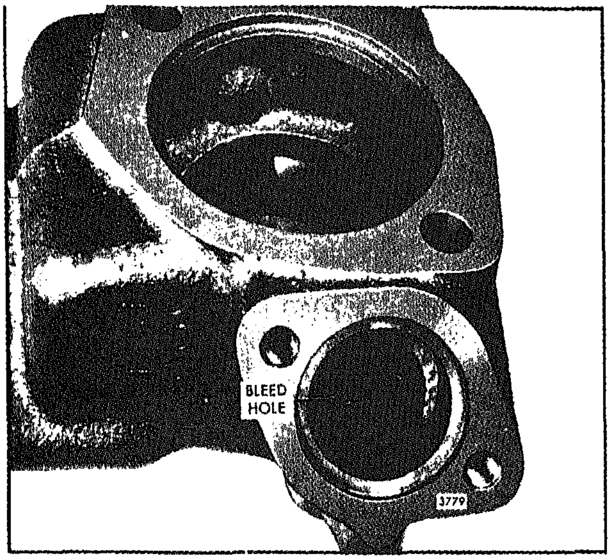


Fig. 5 · Bleed Hole in Thermostat Housing

2. Insert the thermostat into the housing.

3. Install the water outlet elbow and secure it to the housing with two bolts and lock washers.

4. Connect the hose from the radiator or heat exchanger to the water outlet elbow, align and tighten the hose clamps.

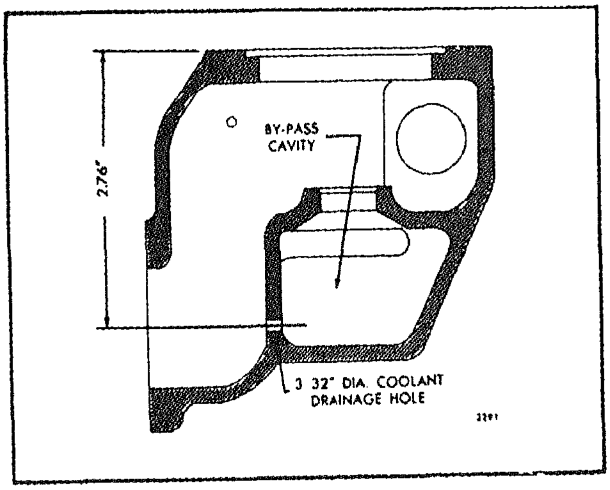


Fig. 6 · Cross-Section of Thermostat Housing
(Early Industrial In-Line Engine)

ENGINE COOLING FAN

The engine cooling fan is driven by a pair of V-drive belts from the crankshaft pulley (Fig. 1).

Effective with engine serial number 3D- new fan hub assemblies are being used on the In-line engines. The new assemblies are similar to the integral cast shaft and bracket design, with tapered roller bearings, currently used on the V-type engines (Fig. 5).

The belt-driven fan is bolted to a combination fan hub and pulley which turns on a sealed ball bearing assembly (former In-line engines) or two tapered roller bearings (current In-line engines). The crankshaft driven fan is bolted to the crankshaft pulley.

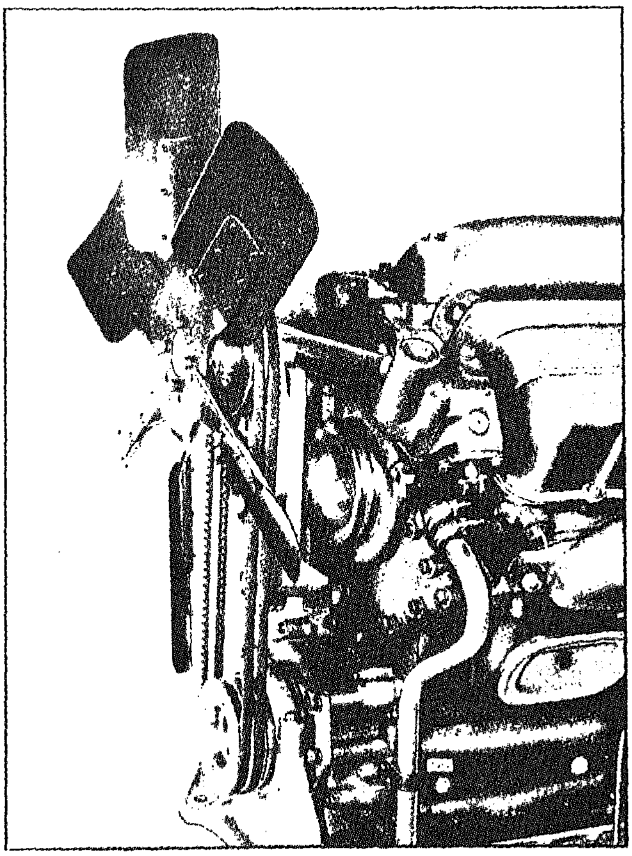


Fig. 1 - Belt-Driven Fan Mounting

Lubrication

The sealed ball bearings, used in the fan hub assembly on the former In-line engines, is pre-lubricated and requires no further lubrication.

The tapered roller bearings, used in the fan hub on current In-line engines, are pressure lubricated prior to assembly. The cavity between the bearings is packed with Chevron BRB No. 2 grease or an equivalent performance grease at the time the hub is assembled. Also the fan hub cap is packed approximately 75% full of grease. Repack the fan hub assembly as outlined in the assembly procedure. The hub cap at the front and a seal at the rear of the hub prevents leakage of the lubricant.

Remove Fan, Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core.

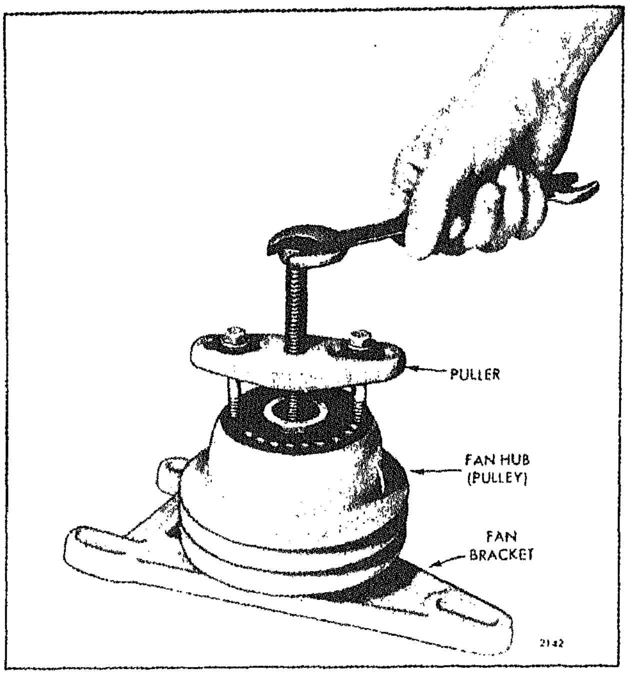


Fig. 3 - Removing Fan Hub (Pulley)

Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan blades, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

1. Remove the attaching bolts and lock washers and remove the fan and spacer (if used).

2. Loosen the fan hub adjusting bracket bolts and remove the drive belts. Then withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

Disassemble Hub and Adjusting Bracket

IN-LINE ENGINES (FORMER):

1. Measure the distance between the rear face of the rim on the pulley and rear face (machined) of the fan adjusting bracket. Record this measurement for reassembly purposes.

2. Remove the fan hub from the shaft with a puller as shown in Fig. 3.

an arbor press. Then
haft and against the
bearing and

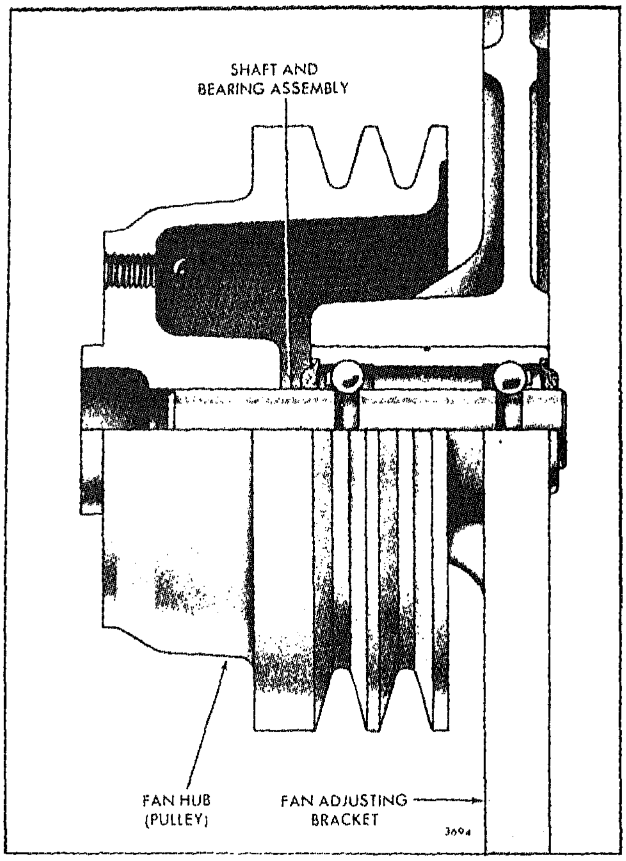


Fig. 4 - Former Fan Hub Assembly (In-Line Engine)

CAUTION: Damage to the bearing will result if force is applied to the shaft.

IN-LINE ENGINES (CURRENT):

1. Remove the fan hub cap.

2. Remove the hub bolt and washer.

3. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.

4. Remove the oil seal and bearing from the fan hub.

5. Remove the bearing spacer, shims and grease retainer.

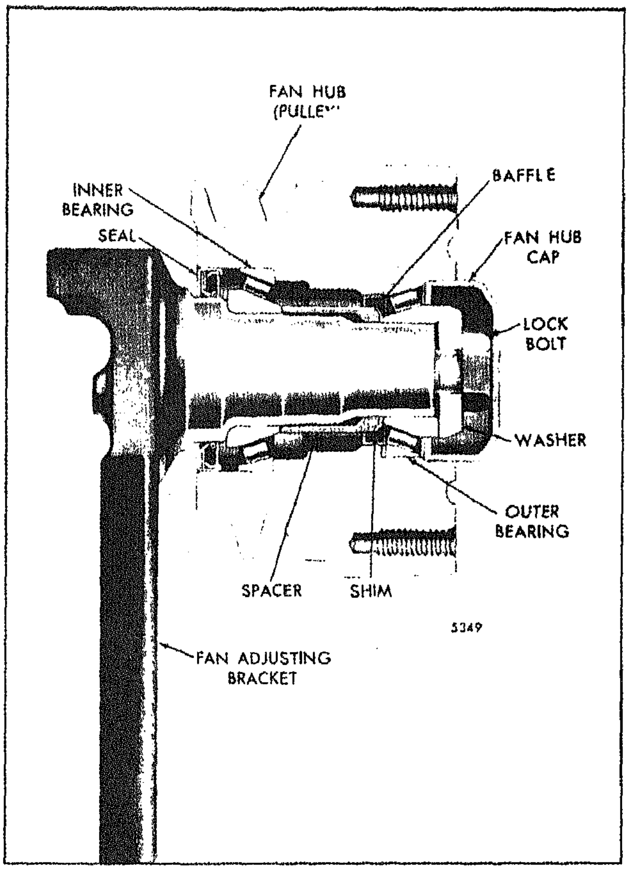


Fig. 5 · Current Fan Hub Assembly (In-Line Engine)

Inspection

Wash the fan and fan hub parts thoroughly with fuel oil, dry them with compressed air and inspect them for wear or damage.

> **NOTE:** Do not wash the permanently sealed bearing which is used in the In-line engine hub assembly. Wipe the bearing and shaft assembly with a clean lintless cloth.

Hold the inner race (shaft of sealed ball bearing assembly) and revolve the outer race of each bearing

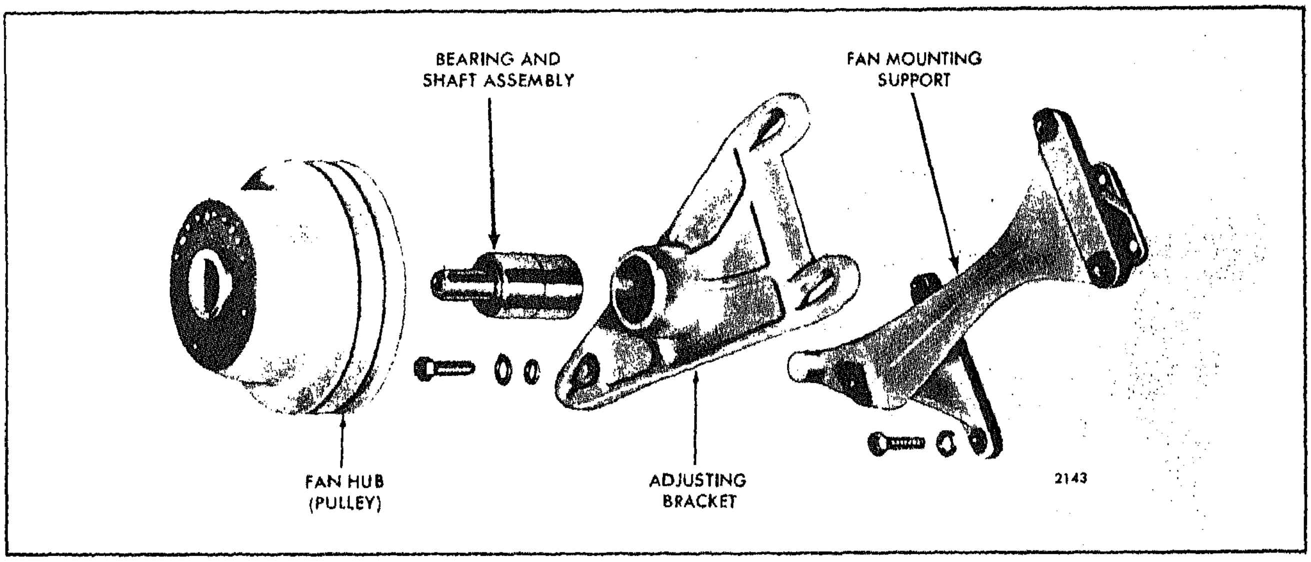


Fig. 8 - Typical Fan Hub and Adjusting Bracket Details and Relative Location of Parts (In-Line Engine)

slowly by hand. If rough or tight spots are detected, replace the bearing.

Examine the fan blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severly worn, replace the pulleys.

Assemble Hub and Adjusting Bracket

IN-LINE ENGINES (FORMER):

Refer to Figs. 4 and 8 and assemble the fan hub and adjusting bracket as follows:

1. Press the shaft and bearing assembly into the adjusting bracket by applying pressure on the outer race of the bearing, using a suitable sleeve, until the bearing is flush with the pulley end of the bracket.

2. Measure the shaft diameter and the pulley bore. It is important that a .001" - .002" press fit be maintained. Then support the bearing end of the shaft and press the fan hub (pulley) on the shaft to the original dimensions taken during disassembly. This will assure proper alignment and clearance of the parts.

The shaft and bearing assembly are permanently sealed and require no lubrication.

IN-LINE ENGINES (CURRENT):

Assemble the fan hub and spindle shown in Fig. 5 as follows:

1. Apply Chevron BRB No. 2 grease or an equivalent performance grease to the rollers of both bearings before installing them in the fan hub (pulley).

2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.

3. Install a new seal with the felt-side flush with the outer edge of the hub.

4. Place the hub over the spindle and install the bearing spacer.

5. Pack the cavity approximately 1/4 full with grease and install the grease baffle.

6. Place the shims against the bearing spacer. Then install the outer bearing with the protruding face of the inner race facing outward from the hub.

7. Place the retaining washer with the breakout side toward the bearing. Install and tighten the bolt to 83-93 lb-ft torque while rotating the pulley.

8. Check the end play in the assembly with the spindle (shaft) in a horizontal position. The end play must be within .001 " to .006 ". If necessary, remove the bolt, washer and outer bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015 ", .020 " and .025 " thickness. Then reassemble the fan hub and check the end play.

9. Fill a new fan hub cap 3/4 full of grease and install it in the end of the fan hub (pulley).

Install Fan, Hub and Adjusting Bracket

New .500 " thick and .800 " thick fan hub spacers and a new fan hub cap replaces the former spacer and cap assemblies to provide spacers compatible with the six bolt hole mounting fan hub assemblies. The spacers (individually or in combination) also provide a means for setting the different clearances between the back of the fan blades and front groove of the crankshaft pulley.

The new spacers have a flange on one side that serves as a pilot for the fan as well as a spacer pilot for the second spacer when two or more spacers are used together.

> **EXAMPLE:** A former 1.800 " thick spacer and cap assembly have been replaced by two .500 " thick spacers, one .800 " thick spacer and the new fan hub cap.

When replacing the former fan hub spacer be sure and include the new cap.

1. Attach the fan hub and adjusting bracket assembly to the bracket support on the engine with bolts, lock washers and plain washers. Do not tighten the bolts.

2. Install the drive belts and adjust the belt tension as outlined in Section 15.1. If used, install the adjusting bracket, bolt and plain washer shown in Fig. 10.

3. Install the fan (and fan spacer and cap, if used) on the hub and secure it with the 5/16 "-18 bolts and lock washers.

WATER FILTER AND CONDITIONER

The engine cooling system water filter and conditioner (Fig. 1) is a compact by-pass type unit with a replaceable element.

A correctly installed and properly maintained water filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity, and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the water passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid-free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the water, forming a protective rust-proof film on all of the metal surfaces of the cooling system (refer to Section 13.3). The other components of the element perform the function of cleaning and preparing the cooling passages while the corrosion inhibitors protect them.

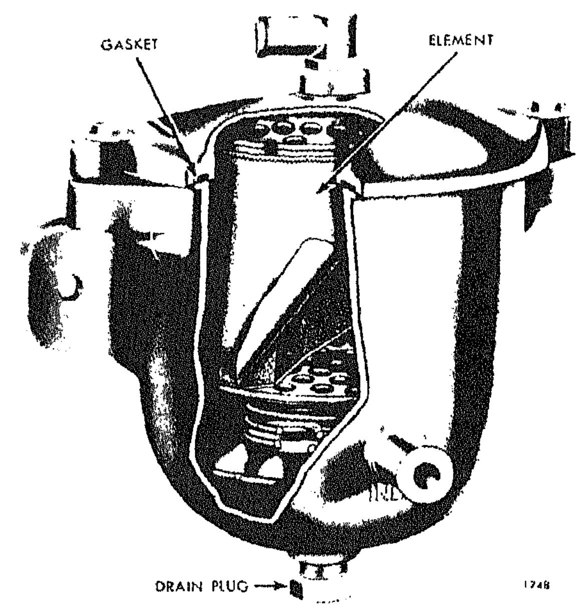


Fig. 1 · Water Filter and Conditioner

Make-up water up to approximately 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

Filter Installation

If a water filter and conditioner is to be installed on an engine which has been in service, drain and flush the cooling system prior to installation of the filter.

Filter Maintenance

Replace the chemically activated element periodically and buff the lower corrosion resistor plate on the former filter each time (discard the plate if excessive metal loss or pitting is evident) to ensure effective protection of the cooling system.

If the water filter is installed on an engine which has previously been in service, it may be necessary to change the filter element two or three times at intervals of 6,000 miles or less to clean up accumulations of scale and rust in the cooling system. It is advisable to drain and flush the system during these initial change intervals.

Change the filter element periodically as outlined in Section 15.1.

If it is necessary for any reason to drain the cooling system before an element change, the treated water should be saved and re-used. If the treated water is discarded, a new filter element must be installed since the protective agents in the used filter will have been partially consumed in treating the discarded water.

Service

Whenever the water filter is removed and reinstalled, the filter must have metal-to-metal contact (grounded), either directly with the mounting surface or through the mounting bolts.

The current water filter includes a non-chromate type element. This element can be used in place of either of the former water filter elements (permanent type anti-freeze or plain water type) and thus provides year around cooling system protection. The current and the former water filter elements are completely interchangeable in the former filter can (refer to Section 13.3).

Replace the element and service the water filter and conditioner as follows:

1. Close the water filter inlet and outlet shut-off valves. If shut-off valves are not provided, vise grip pliers can be used to clamp each hose closed during the filter change.

2. Remove the filter cover-to-filter body bolts.

3. Remove and discard the element.

4. Remove and discard the corrosion resistor plates, if the former type filter is used.

5. Remove the sludge and sediment and wash the sump and filter body. Dry it thoroughly with compressed air.

6. Replace the drain plug, if removed, in the bottom of the filter.

7. Insert the new element.

8. Use a new filter cover gasket, install the filter cover, and tighten the bolts evenly.

9. Open the inlet and outlet lines by opening the shut-off valves or removing the vise grip plier clamps.

10. Operate the engine and check for leaks. The top of the filter and the outlet line should feel warm to the touch with the rise in coolant temperature. If not, disconnect the filter outlet line at the end opposite the filter connection to bleed the air from the system and reconnect the line. Use caution to minimize coolant loss.

SPECIFICATIONS - SERVICE TOOLS

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	TORQUE (lb-ft)	THREAD SIZE	TORQUE (lb-ft)
1/4 -20	7-9	9/16-12	90-100
1/4 -28	8-10	9/16-18	107-117
5/16-18	13-17	5/8 -11	137-147
5/16-24	15-19	5/8 -18	168-178
3/8 -16	30-35	3/4 -10	240-250
3/8 -24	35-39	3/4 -16	290-300
7/16-14	46-50	7/8 - 9	410-420
7/16-20	57-61	7/8 -14	475-485
1/2 -13	71-75	1 - 8	580-590
1/2 -20	83-93	1 -14	685-695

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)
Water pump cover bolt	5/16-18	6-7
Raw water pump drive gear retaining nut	5/8 -18	30-35

SERVICE TOOLS

TOOL NAME	TOOL NO.
Holder	J 358-1
Remover and installer	J 1930
Installer	J 22091
Puller	J 4794-01
Handle	J 7092-2
Plates	J 8329

SECTION 6

EXHAUST SYSTEM

CONTENTS

EXHAUST SYSTEM

Fan and radiator cooled engines are equipped with an air-cooled exhaust manifold.

The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

EXHAUST MANIFOLD (AIR COOLED)

The exhaust manifolds
has an outlet to accommodate a square exhaust outlet flange (Fig. 1)

Current manifolds, flanges (square) and flange gaskets have SAE standard dimensions.

Remove Exhaust Manifold

1. Disconnect the exhaust pipe or muffler from the exhaust manifold flange.

3. Loosen, but do not remove, one of the center exhaust manifold nuts. Remove the other nuts and washers.

4. Support the manifold and remove the center nut and washer.

5. Remove the manifold and gasket from the cylinder head.

Inspection

Remove any loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. Clean the manifold and check for cracks, especially in the holding lug areas.

Clean all traces of gasket material from the cylinder head.

Examine the exhaust manifold studs. Replace damaged studs. Apply sealant to the threads and drive new studs to 25-40 lb-ft torque (1.40" to 1.50" height).

Install Exhaust Manifold

1. Place a new gasket over the studs and against the cylinder head.

2. Position the exhaust manifold over the studs and hold it against the cylinder head.

3. Install the washers and nuts on the studs. If beveled (dished) washers are used, position them so that the crown side faces the nut.

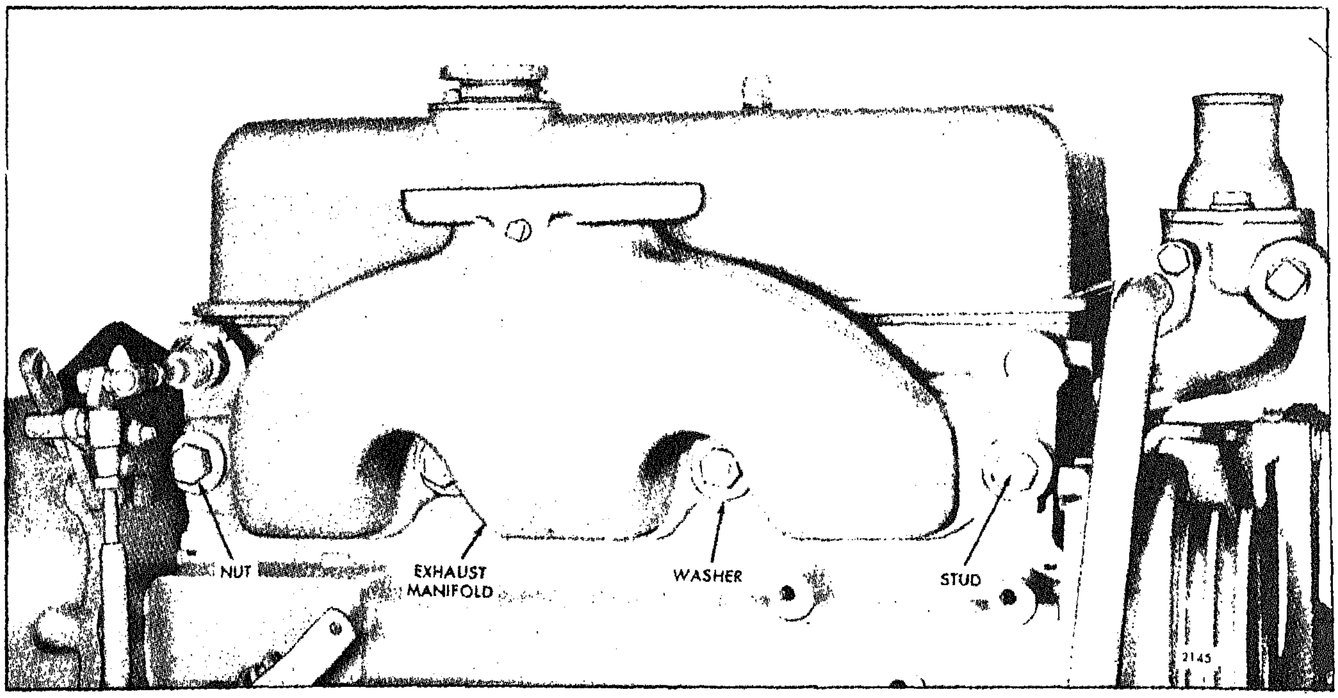


Fig. 1 - Typical Air-Cooled Exhaust Manifold (Square Flange) Mounting

Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30-35 lb-ft torque.

5. Connect the exhaust pipe or muffler to the exhaust manifold flange.

SECTION 7

ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS

CONTENTS

ELECTRICAL SYSTEM

A typical engine electrical system generally consists of a starting motor, a battery-charging generator (alternator), a transistor combination voltage regulator, current regulator and cutout relay to protect the electrical system, a storage battery and the necessary wiring.

Additional equipment such as an engine protective system may also be included.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and maintenance manuals. The manuals may be obtained from United Delco Division, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Allison. For electrical equipment manufactured by Delco-Remy Division, repair service and parts are available through United Delco Division branches and repair stations.

BATTERY-CHARGING GENERATOR (D.C. and A.C.)

The battery-charging circuit consists of a generator (alternator), regulator, battery and the wiring. The battery-charging generator is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the generator.

The alternating current self-rectifying generator (alternator), Figs. 2 and 3, is especially beneficial on an engine with extra electrical accessories and one that has to operate for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase A.C. voltage to provide D.C. voltage at the battery terminal of the generator, thereby eliminating the need for an external rectifier. The alternator is also available in a variety of sizes and types.

The proper selection of a generator which will meet the needs of the battery-charging circuit on the particular engine is mandatory. This, together with adherence to the recommended maintenance procedures, will reduce generator troubles to a minimum. Since most generators adhere to the same basic design, the maintenance, removal and installation procedures for all are similar.

Generator Maintenance

1. Maintain the proper drive belt tension. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the generator drive.

2. Lubricate the generator bearings as outlined in the *Lubrication and Preventive Maintenance Chart* in Section 15.1.

Remove Generator

1. Disconnect all of the leads from the generator and tag each one to ensure correct re-installation.

2. Loosen the generator mounting bolts and nuts and the adjusting strap bolt. Then, remove the generator drive belts.

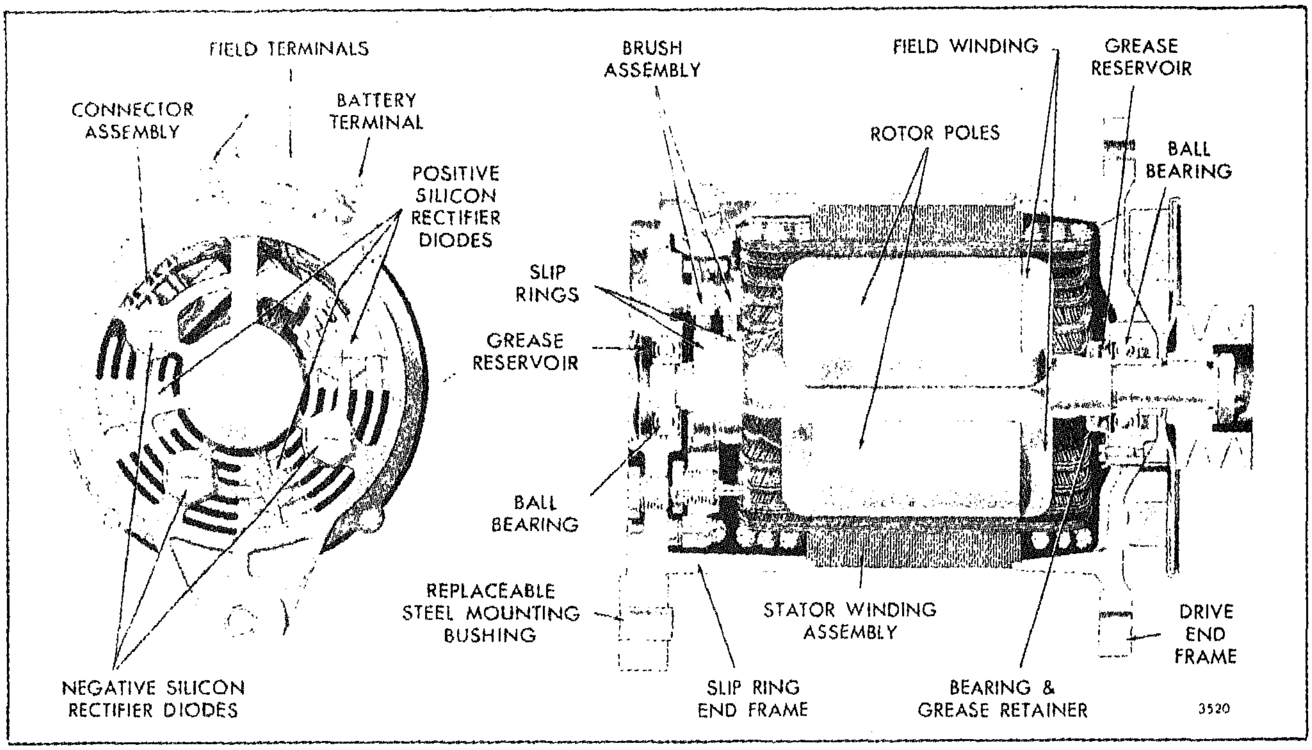


Fig. 2 · 30 DN Type 100 A.C. Self-Rectifying Generator (Alternator)

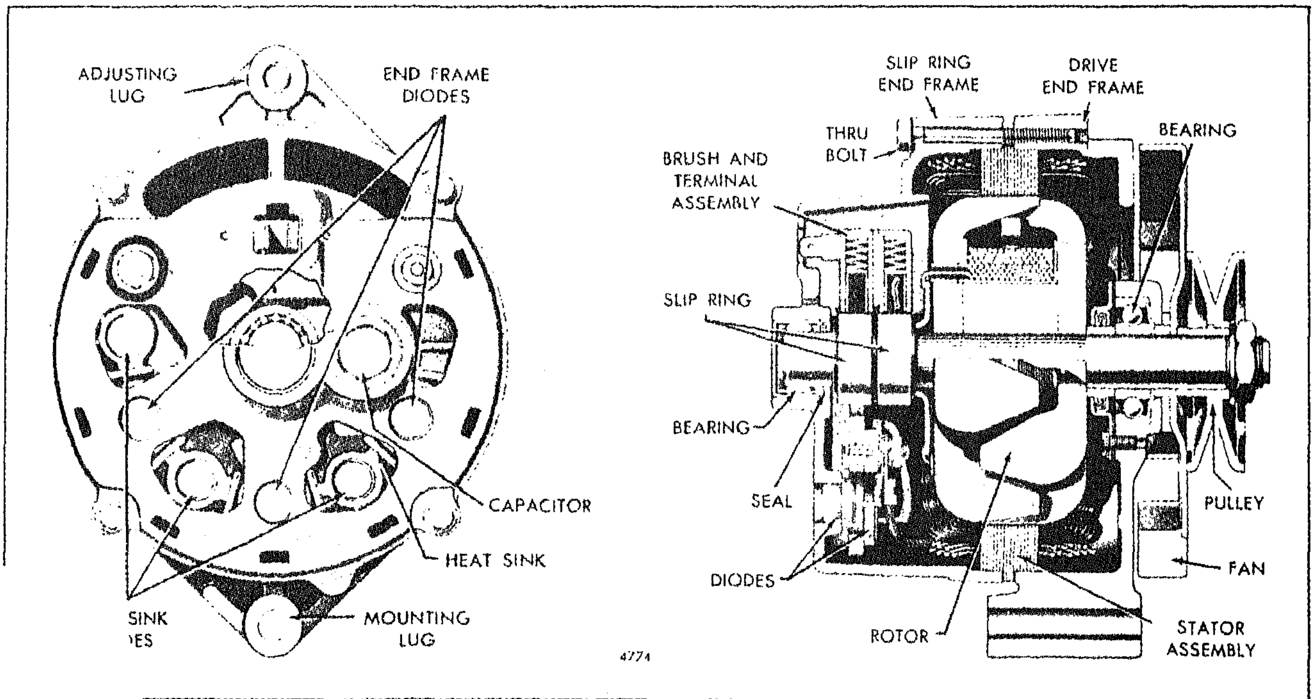


Fig. 3 · 10 DN Type 112 A.C. Self-Rectifying Generator (Alternator)

3. While supporting the generator, remove the adjusting strap bolt and washers and the mounting bolts, washers and nuts. Then remove the generator.

4. Remove the pulley assembly if the generator is to be replaced.

Install Generator

1. Install the generator drive pulley, if it was removed. Tighten the pulley retaining nut to 60 lb-ft torque.

> **NOTE:** If the pulley was not removed, check the retaining nut for proper torque.

2. Position the generator on the mounting brackets and start the bolts, with lock washers, through the bolt holes in the generator end frames. If nuts are used, insert the bolts through the bolt holes and then install the lock washers and nuts.

3. Align the threaded hole in the extension ear of the drive end frame with the slot in the adjusting strap. Start the bolt, with the lock washer and plain washer, through the slot of the adjusting strap and into the threaded hole in the generator end frame.

4. Place the drive belts in the grooves of the pulleys.

5. Adjust the generator belt tension as outlined in Section 15.1.

6. Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the generator. Keep all connections clean and tight.

Alternator Precautions

Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires or the field wires between the generator and the regulator.

Grounding an A.C. generator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running, or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

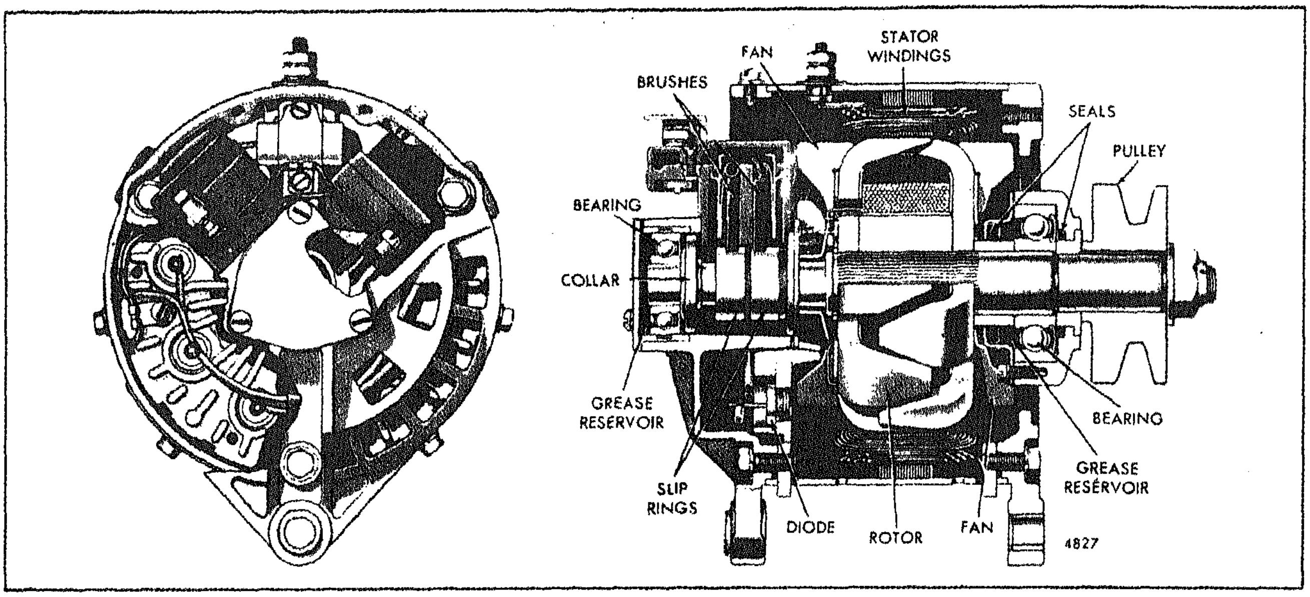


Fig. 4 · 20 DN Type 250 A.C. Self-Rectifying Generator (Alternator)

Accidentally reversing the battery connections must be avoided.

Never disconnect the battery while an alternator is in operation. Disconnecting the battery may result in damage to the generator diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the battery connected or as a booster for battery output.

Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.

If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to be sure that a ground strap is present and is correctly installed.

BATTERY-CHARGING GENERATOR REGULATOR

A.C. CHARGING CIRCUIT

The alternating current generator regulator is similar in outward appearance to the regulator used with the D.C. generator. The D.C. and A.C. regulators are NOT interchangeable.

The internal wiring circuits of all standard A.C. generator regulators are similar, but the internal connections vary somewhat according to the method used to control the circuit breaker relay.

There are two and three unit standard A.C. generator regulators; the two unit regulators have a circuit breaker relay controlled by a relay rectifier or by an oil pressure switch and the three-unit regulators have a circuit breaker relay controlled by a built-in control relay.

The generator field circuit is insulated in the generator and grounded in the regulator. This type of connection is designated as Circuit "A".

> **NOTE:** Each type of regulator is used with a certain circuit. Do not attempt to interchange regulators.

The two unit A.C. generator regulator has a circuit breaker relay and a voltage regulator unit while the three unit regulator is also equipped with a control relay in addition to the other two units.

CIRCUIT BREAKER RELAY

The circuit breaker relay has a core with the winding made up of many turns of fine wire. This core and winding are assembled into a frame. A flat steel armature is attached to the frame by a hinge and is centered above the core. Two contact points, supported by two flat springs on the armature, are located above two stationary contact points. The upper and lower contact points are held apart by the tension of a flat spring riveted to the top side of the armature.

Operation

When the D.C. voltage reaches the value for which the circuit breaker relay is adjusted, the magnetism induced in the core by current flow in the winding is sufficient to overcome the armature spring tension and the relay points close. Closing of the contact points connects the D.C. side of the power rectifier to the battery so that current will flow to the battery whenever the generator is driven at sufficient speed.

The relay contact points remain closed as long as the D.C. voltage is enough to hold the relay armature against the core. They open when the voltage decreases to a value at which the magnetic pull of the core can no longer overcome the armature spring tension.

VOLTAGE REGULATOR

The voltage regulator unit has a core with a single shunt winding. This winding also consists of fine wire and is connected across the D.C. side of the power rectifier. The assembly and parts are similar to the circuit breaker relay. The matching upper contact point is supported by a detachable contact support insulated from the frame.

Operation

If the voltage regulator unit is not operating, the generator field circuit is completed to ground through the contact points which are held closed by the tension of a spiral spring acting on the armature.

When the D.C. voltage of the A.C. - D.C. system reaches the value for which the voltage regulator is adjusted, the magnetic field produced by the shunt winding overcomes the armature spring tension and pulls the armature down, causing the contact points to separate. When the contact points separate, resistance is introduced into the field circuit. The resistance decreases the field current causing a corresponding decrease in generator voltage and magnetic pull on the regulator armature. This allows the armature spring tension to re-close the contact points. When the voltage again reaches the value for which the voltage regulator is adjusted, this cycle repeats and continues to repeat many times a second, thus limiting the voltage to the value for which the regulator is set.

With the voltage limited in this manner, the generator supplies varying amounts of current to meet the various states of battery charge and electrical load.

Voltage regulators are compensated for variations in temperature by means of a bi-metal thermostatic hinge on the armature. The effect of this hinge causes the regulator to adjust at a higher voltage when cold, which partly compensates for the fact that a high voltage is required to charge a cold battery.

CONTROL RELAY

In addition to a circuit breaker and a voltage regulator, the three-unit regulator has a control relay unit. This unit has a core with a single shunt winding connected from the "SW" terminal of the regulator to ground. The winding and core are assembled into a frame. A flat steel armature supporting the upper one of two relay contacts is attached to the frame by a hinge and is centered above the core. The lower contact point is supported by a detachable contact support insulated from the frame. An armature stop is assembled above the upper contact.

Operation

When the ignition switch is "OFF", the contact points are held apart by the tension of a spiral spring acting on the armature. When the ignition switch is turned "ON", battery current flows through the control relay winding to ground. The magnetic field produced by the winding overcomes the armature spring tension and pulls the armature down causing the contact points to close. This completes the circuit to ground for the circuit breaker relay winding so that it can operate when the D.C. voltage from the power rectifier reaches the value for which the circuit breaker relay is adjusted. The control relay contact points remain closed until the ignition switch is turned "OFF".

TRANSISTORIZED AND TRANSISTOR REGULATORS

In addition to the standard regulator, there are two other types of regulators being used with the self-rectifying A.C. generators in the battery-charging circuit. One is a transistorized regulator which contains a vibrating voltage regulator unit and a field relay unit. The other is a transistor regulator which contains no moving parts and is used with a separately mounted field relay.

TRANSISTORIZED REGULATOR

The transistorized regulator (Fig. 3), for use on a negative ground circuit, contains a vibrating voltage regulator unit and a field relay unit. The regulator uses a single transistor and two diodes. The transistor works in conjunction with the conventional voltage unit having a vibrating contact point to limit the generator voltage to a pre-set value. A field discharge diode reduces arcing at the voltage regulator contacts by dissipating the energy created in the generator field windings when the contacts separate. A suppression diode prevents damage from transient voltages which may appear in the system.

Certain transistorized regulators are equipped with a choke coil to permit the installation of a capacitor between the regulator and the "BAT" terminal on installations experiencing radio interference. The capacitor suppresses the radio noise and the choke coil

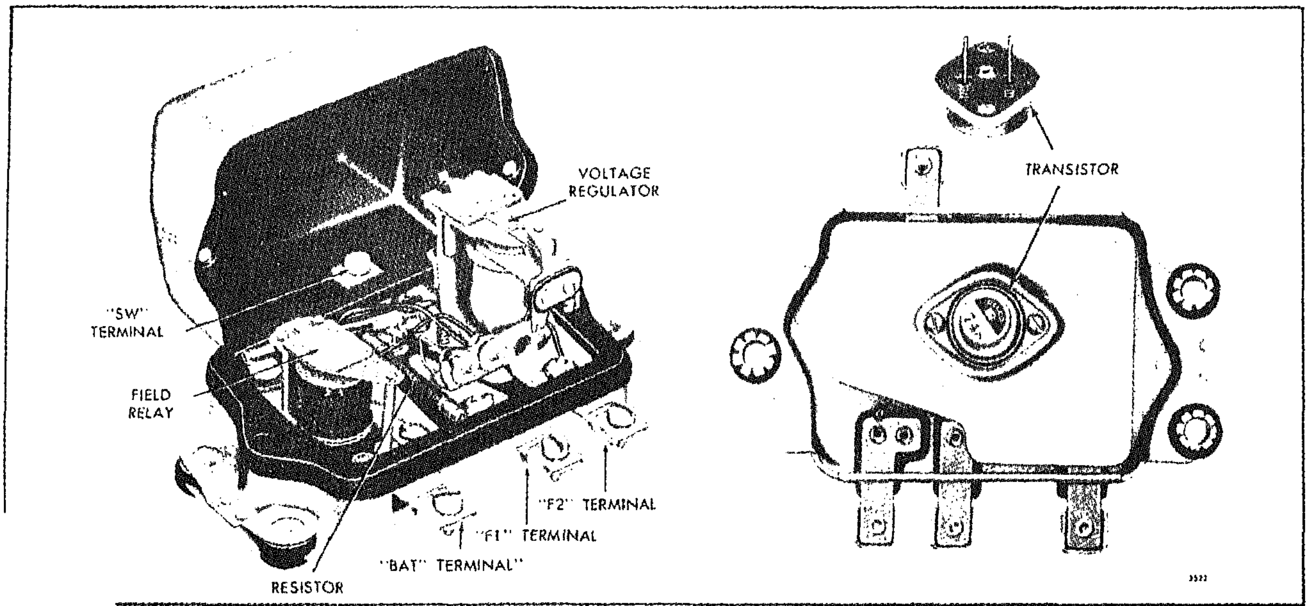


Fig. 3 - Transistorized Regulator

acts to prevent oxidation of the voltage regulator contacts. Regulators incorporating the choke coil are identified by a spot of green paint on the regulator base, next to the single mounting bolt hole.

CAUTION: A capacitor must not be installed unless the transistorized regulator incorporates the choke coil.

Operation

When the engine starting switch is closed, the field relay winding is energized and causes the contacts to close. Current then flows from the battery through the relay contacts to the regulator "F2" terminal. From this point, the current flows through the generator field winding and then through the transistor and voltage contact points to ground.

As the generator speed increases, the increased voltage from the generator "BAT" terminal is impressed through the field relay contacts across the regulator shunt winding. The magnetism created in the winding causes the voltage contacts to open, thus causing the transistor to shut off the field current. The generator voltage then decreases and the voltage contacts re-close. This cycle repeats many times per second, thereby limiting the generator voltage to the value for which the regulator is set.

The magnetism produced in an accelerator winding, when the voltage contacts are closed, aids the shunt winding in opening the contacts. When the contacts are open, the absence of the magnetism in the accelerator winding allows the spring to immediately re-close the contacts. This action speeds up the vibration of the contacts.

CAUTION: Do not short across or ground any of the terminals on the regulator or the generator and *do not* attempt to polarize the generator.

TRANSISTOR REGULATOR

The transistor regulator is composed principally of transistors, diodes, capacitors and resistors to form a completely static electrical unit containing no moving parts.

The transistor is an electrical device which limits the generator voltage to a pre-set value by controlling the generator field current. The diodes, capacitors and resistors act together to aid the transistor in performing this function, which is the only function that the regulator performs in the charging circuit.

The voltage at which the generator operates is determined by the regulator adjustment. Once adjusted, the generator voltage remains almost constant, since the regulator is unaffected by length of service, changes in temperature or changes in generator output and speed.

A separately mounted field relay connects the regulator "POS" terminal and the generator field windings to the battery when the engine starting switch is closed.

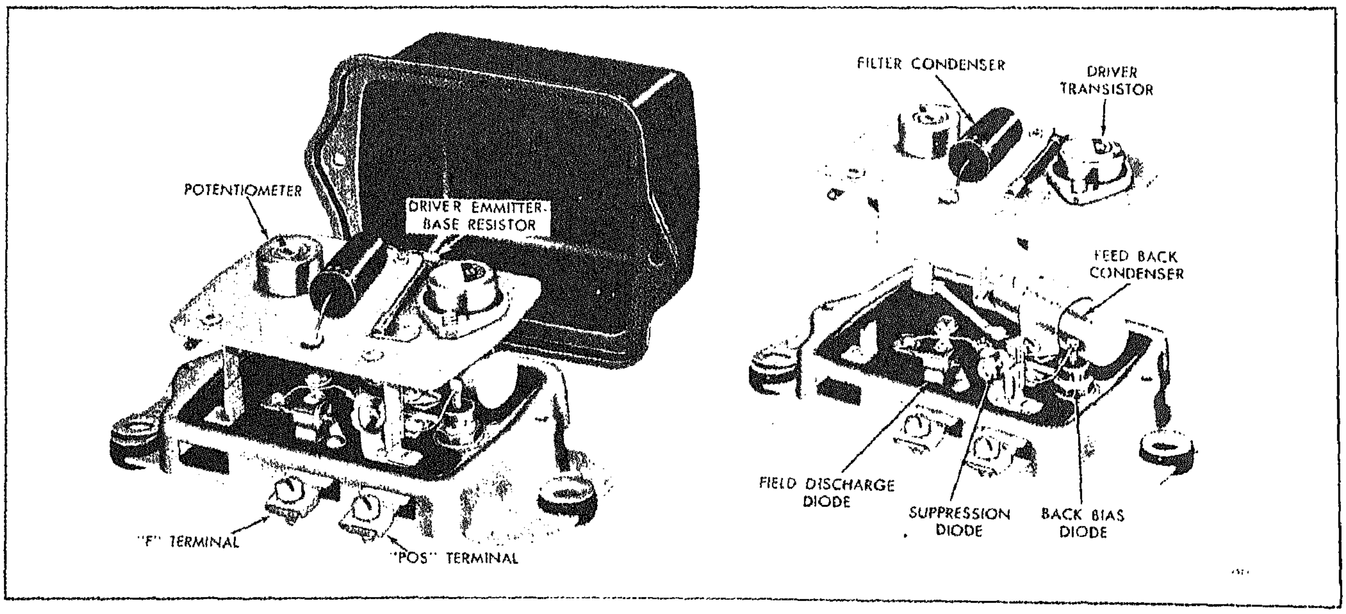


Fig. 4 - Transistor Regulator (Negative Ground Circuits Only)

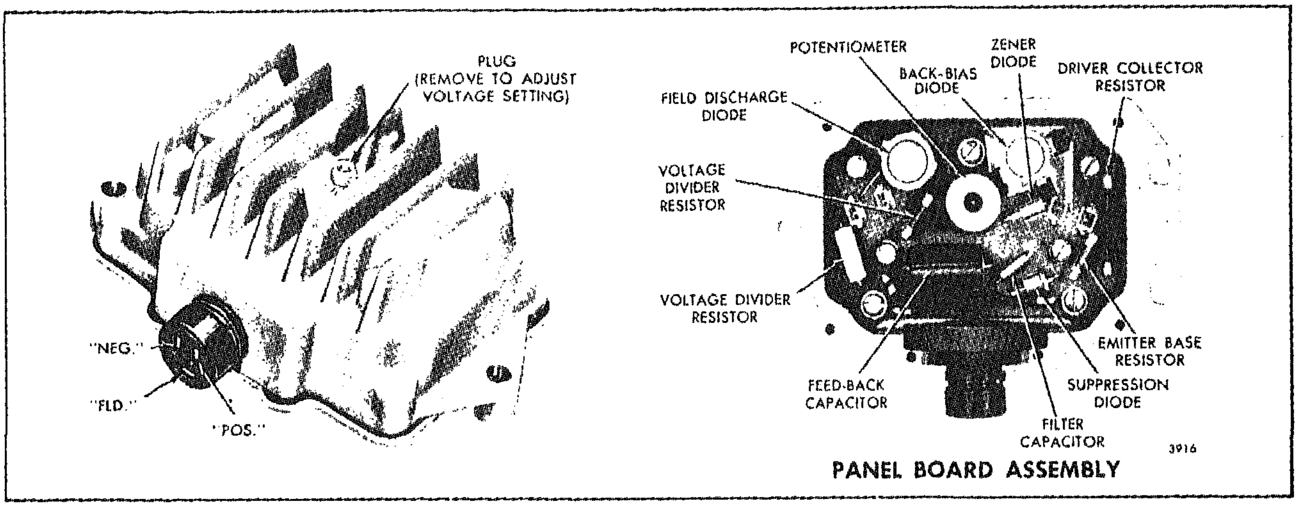


Fig. 5 - Transistor Regulator with Plug-In Connections

The voltage regulator illustrated in Fig. 4 is designed for negative ground battery-charging circuits only. It has two exposed terminals. The voltage setting may be adjusted by relocating a screw in the base of the regulator.

The voltage regulator shown in Fig. 5 has shielded plug-in connections and requires a cable and plug assembly to connect the regulator into the battery-charging circuit. This type of regulator may be used in negative ground, positive ground and insulated charging circuits. The voltage setting may be adjusted by removing a plug in the cover and turning a slotted adjusting button inside the regulator.

Operation

When the engine starting switch is closed, the field relay winding is energized, which causes the relay contacts to close.

In the **negative ground circuit** with the field relay contacts closed and the engine not running, generator field current can be traced from the battery through the relay contacts to the regulator "POS" terminal. Current then continues through the back-bias diode (D-1) and power transistor (TR-1) to the regulator "FLD" terminal, and then through the generator field winding to ground, completing the circuit back to the battery.

When the generator begins to operate, A.C. voltages are induced in the stator windings. These voltages are changed, or rectified, to a D.C. voltage which appears at the output, or "BAT", terminal on the generator. The generator then supplies current to charge the battery and operate vehicle accessories.

As generator speed increases, the voltage reaches the pre-set value and the components in the regulator cause transistor TR-1 to alternately "turn off" and "turn on" the generator field voltage. The regulator thus operates to limit the generator output voltage to the pre-set value.

In the **positive ground circuit**, when the switch is closed and the engine is not running, the field current can be traced from the battery positive ground to generator ground, and then to the regulator "POS" terminal. The current continues through diode D-1 and transistor TR-1 to the regulator "FLD" terminal, and then through the field winding and field relay contacts back to the battery, thus completing the circuit. Except for this primary difference, this circuit operates in the same manner as that described for the negative ground circuit.

REGULATOR PRECAUTIONS

Never short or ground the regulator terminals; *do not attempt to polarize the circuit.*

Make sure all connections in the charging circuit are tight to minimize resistance.

Refer to "A.C. Generator Precautions" in Section 7.1.

STARTING MOTOR

The starting motor is mounted on the flywheel housing as illustrated in Fig. 1. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor. To accomplish this, the starting motor is equipped with a Sprag-type overruning clutch.

A solenoid switch, mounted on the starting motor housing, operates the Sprag-type overrunning clutch drive by linkage and a shift lever (Figs. 2 and 3). When the starting switch is engaged, the solenoid is energized and shifts the starting motor pinion into mesh with the flywheel ring gear and closes the main contacts within the solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. To protect the armature from excessive speed when the engine starts, the clutch "overruns", or turns faster than the armature, which permits the pinion to disengage itself from the flywheel ring gear.

The solenoid plunger and shift lever is totally enclosed to protect them from dirt, water and other foreign material.

In the heavy-duty clutch type (Fig. 3), an oil seal, between the shaft and the lever housing, and a linkage seal prevents the entry of transmission oil into the main frame of the starting motor and solenoid case, allowing the motor to be used on wet clutch applications.

The nose housing on the Sprag clutch type starting motor can be rotated to obtain a number of different solenoid positions with respect to the mounting flange.

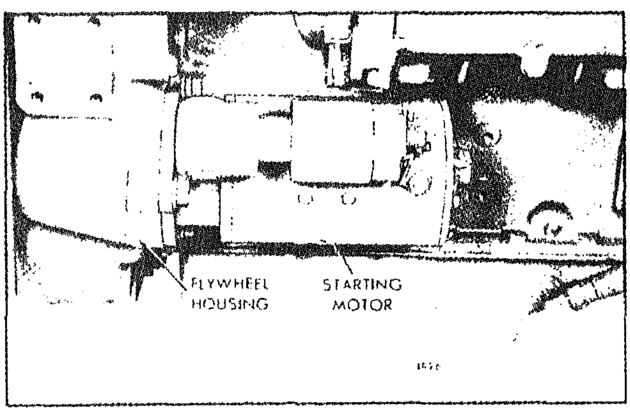


Fig. 1 - Starting Motor Mounting

When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

Starter with Intermediate-Duty Clutch (In-Line Engines)

The lever housing and the commutator end frame are held to the field frame by bolts extending from the end frame to threaded holes in the lever housing. The nose housing is held to the lever housing by internal attaching bolts extending from the lever housing to threaded holes in the nose housing (Fig. 2). With this arrangement, it is necessary to partially disassemble the motor to provide access to the nose housing attaching bolts. Relocate the nose housing as follows:

1. Remove the electrical connector and the screws attaching the solenoid assembly to the field frame. Then remove the bolts from the commutator end frame.

2. Separate the field frame from the remaining assembly and pull the armature away from the lever housing until the pinion stop rests against the clutch pinion. This will provide access to the nose housing attaching bolts.

3. Remove the nose housing attaching bolts with a box wrench or open end wrench.

4. Turn the nose housing to the required position.

> **NOTE:** The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failures.

5. Reinstall the nose housing attaching bolts and tighten them to 11-15 lb-ft torque.

6. Reassemble the motor.

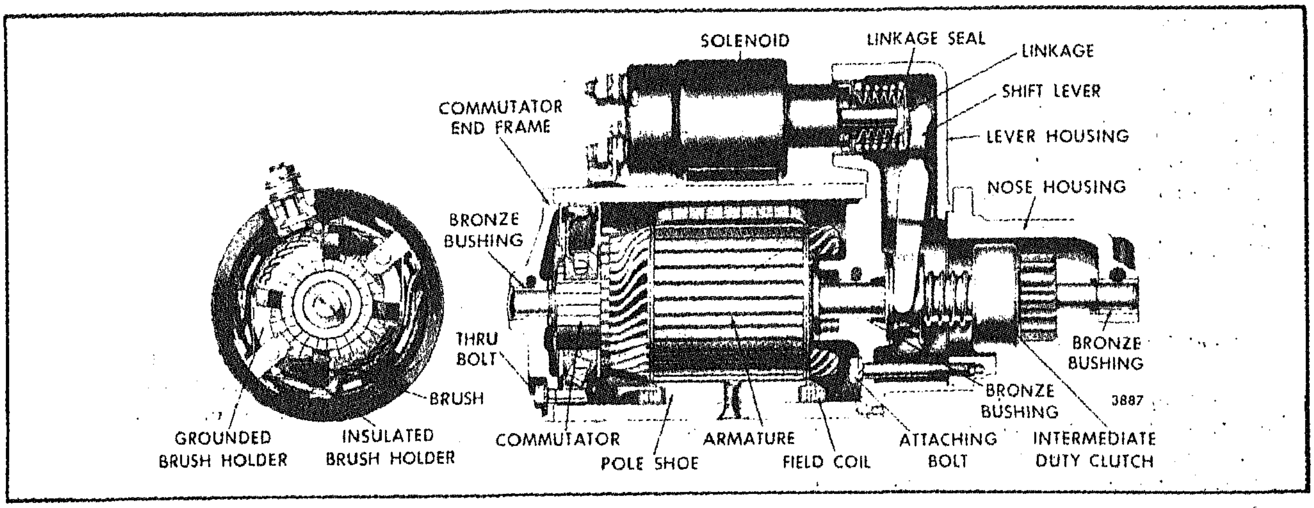


Fig. 2 · Cross-Section of Motor with Intermediate-Duty Clutch

Lubrication

The starting motor bearings (bushings) are lubricated by oil saturated wicks which project through each bronze bushing (one at each end and one at the center) and contact the armature shaft. Oil can be added to each wick by removing a pipe plug which is accessible on the outside of the motor (refer to Section 15.1).

Flywheel Ring Gears

The starting motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth. Flywheel ring gear teeth have either no chamfer or a Bendix chamfer. The Sprag clutch cannot be used with a ring gear with a Dyer chamfer.

Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.

2. Disconnect the starting motor cables and solenoid wiring.

   NOTE: Tag each lead to ensure correct connections when the starting motor is reinstalled.

3. Support the motor and remove the three bolts and lock washers which secure it to the flywheel housing. Then pull the motor forward to remove it from the flywheel housing.

Check the starting motor, if required, in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8"-11 starter attaching bolts to 137-147 lb-ft torque.

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 16-30 **lb-in** torque and the 1/2" x 13 connections to 20-25 lb-ft torque.

TROUBLE SHOOTING - SPECIFICATIONS - SERVICE TOOLS

TROUBLE SHOOTING

CHECKING ENGINE ELECTRICAL GENERATING SYSTEM

In analyzing generator-regulator operation, check for one of the five following conditions.

1. A *fully charged battery* and *low charging rate* -- this indicates normal generator-regulator operation.

2. *Low battery* and *high charging rate*--indicates normal generator-regulator operation.

3. A *fully charged battery* and a *high charging rate*--this indicates the voltage regulator is not reducing the generator output as it should and will damage the battery--and may be caused by improper voltage regulator setting, defective regulator unit, short circuit or poor connections in the generator or regulator wiring or high battery temperature.

4. *Low battery* and *low or no charging rate*--indicates improper or no regulator operation--and may be due to loose connectons, damaged wires, low voltage or current regulator setting, oxidized contact points or a defective generator.

5. *Excessive arcing at contact points*--may be due to oxidized or misaligned contact points, defective regulator winding, poor cable connections or other causes.

If one of the latter three conditions exists, refer to the "Delco-Remy" electrical equipment operation and maintenance handbooks DR 324, DR 324A and DR 324S for correction of the problems. These manuals may be obtained from United Motors Service.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	TORQUE (lb-ft)	THREAD SIZE	TORQUE (lb-ft)
1/4 -20	7-9	9/16-12	90-100
1/4 -28	8-10	9/16-18	107-117
5/16-18	13-17	5/8 -11	137-147
5/16-24	15-19	5/8 -18	168-178
3/8 -16	30-35	3/4 -10	240-250
3/8 -24	35-39	3/4 -16	290-300
7/16-14	46-50	7/8 - 9	410-420
7/16-20	57-61	7/8 -14	475-485
1/2 -13	71-75	1 - 8	580-590
1/2 -20	83-93	1 -14	685-695

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)
Tachometer drive cover bolt	7/16 -14	30-35
Tachometer drive cover bolt	1/2 -13	30-35
Tachometer drive shaft (blower)	1/2 -20	55-65

SERVICE TOOLS

TOOL NAME	TOOL NO.
Puller set	J 5901
Slide hammer	J 5901-1
Tachometer drive shaft remover	J 5901-3
Tachometer drive alignment tool set	J 23068
Tool No. 1 (.310")	J 23068-1
Tool No. 2 (.313")	J 23068-2
Tool No. 3 (.375")	J 23068-3

SECTION 13

OPERATING INSTRUCTIONS

CONTENTS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow the instructions in Sections 13 and 14 of this manual. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

> **NOTE:** When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart*, Section 15.1.

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Remove the filler cap and fill the cooling system with clean, soft water or a protective solution consisting of high boiling point type antifreeze, if the engine will be exposed to freezing temperatures (refer to *Engine Coolant* in Section 13.3). Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

Use a quality rust inhibitor if only water is used in the cooling system.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 25 psi oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use *heavy-duty* lubricating oil as specified under *Lubricating Oil Specifications* in Section 13.3. Then remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the full mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy-duty* lubricating oil as specified under *Lubricating Oil Specifications* in Section 13.3. Then pre-lubricate the upper engine parts by removing the valve rocker cover(s) and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with clean engine oil. *Do not overfill.*

Transmission

Fill the transmission case torque converter supply tank to the proper level with the lubricant specified under *Lubrication and Preventive Maintenance* in Section 15.1.

Fuel System

Fill the fuel tank with the fuel specified under *Diesel Fuel Oil Specifications* in Section 13.3.

If the unit is equipped with a fuel valve, it must be opened.

To ensure prompt starting, fill the fuel system between the pump and the fuel return manifold with fuel. If the engine has been out of service for a considerable length of time, prime the filter between the fuel pump and the injectors. The filter may be primed by removing the plug in the top of the filter cover and slowly filling the filter with fuel.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance* in Section 15.1.

Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

> **NOTE:** When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Generator Set

Where applicable, fill the generator end bearing housing with the same lubricating oil as used in the engine.

A generator set should be connected and grounded in accordance with the applicable local electrical codes.

> **CAUTION:** The base of a generator set must be grounded.

Clutch

Disengage the clutch, if the unit is so equipped.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15.1.

A manual shut-down system is incorporated in the unit, the control must be set in the open position before starting the engine. The blower will be seriously damaged if operated with the air shut-off valve in the closed position.

Starting at air temperatures below 40 ° F. requires the use of a cold weather starting aid. See *Cold Weather Starting,* Section 12.6.

The instructions for the use of a cold weather fluid starting aid will vary dependent on the type being used. Reference should be made to these instructions before attempting a cold weather start.

> **CAUTION:** Starting fluid used in capsules is highly inflammable, toxic and possesses anesthetic properties.

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the speed control lever at part throttle, then bring it back to the desired no-load speed. In addition, on mechanical governors, make sure the stop lever on the governor cover is in the *run* position.

Then press the starting

motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

CAUTION: To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. Refer to the *Trouble Shooting Charts* in Section 15.2.

Warm-Up

Run the engine at part throttle and no-load for approximately five minutes, allowing it to warm-up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

Engine Temperature

Normal engine coolant temperature is 160 ° F. to 185 ° F.

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately 10 minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy duty* lubricating oil specified under *Lubricating Oil Specifications* in Section 13.3.

Cooling System

Remove the radiator or heat exchanger tank cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or a high boiling point type antifreeze.

Transmission

Check and, if necessary, replenish the oil supply in the transmission.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

> **NOTE:** When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Normal Stopping

1. Release the load and decrease the engine speed. Put all shift levers in the *neutral* position.

2. Allow the engine to run at half speed or slower with no load for a short time, then move the stop lever to the *stop* position to shut down the engine.

Emergency Stopping

If the engine does not stop after using the normal stopping procedure, pull the "Emergency Stop" knob all the way out. This control cuts off the air to the engine. Do not try to restart again until the cause for the malfunction has been found and corrected.

> **CAUTION:** The emergency shut-down system should never be used except in an emergency. Use of the emergency shut-down can cause oil to be sucked past the oil seals and into the blower housing.

The air shut-off valve, located on the blower air inlet housing, must be reset by hand and the "Emergency Stop" knob pushed in before the engine is ready to start again.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Exhaust System

Drain the condensation from the exhaust line or silencer.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open. Open the raw water drains of a heat exchanger cooling system.

Crankcase

Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.

Transmission

Check and, if necessary, replenish the oil supply in the transmission.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to *Lubrication and Preventive Maintenance* and perform all of the daily maintenance operations. Also perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which became apparent to the operator during the last run.

ENGINE OPERATING CONDITIONS

The engine operating charts are included as an aid for engine operation and trouble shooting. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Make sure that the readings represent true values, and that instruments are accurate, before attempting to make corrections to the engine.

3-53 IN-LINE ENGINE

(4-Valve Cylinder Head)

	2200 rpm	2500 rpm	2800 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40-60	40-60	40-60
Minimum for safe operation	30.0	32.0	32.0
*Lubricating oil temperature (degr. F.) - max.	200-235	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. at full load:			
At zero exhaust back pressure	3.7	4.8	6.1
At maximum exhaust back pressure	5.4	8.0	9.3
Air inlet restriction (inches water) - full load max.:			
Dirty air cleaner - oil bath or dry type	18.8	23.0	25.0
Clean air cleaner - oil bath or dry type with precleaner	12.0	14.0	16.0
Clean air cleaner - dry type without precleaner	7.4	8.7	10.0
Crankcase pressure (inches water) - max.	0.8	0.9	1.0
Exhaust back pressure (inches mercury) - max.:			
Full load	3.0	4.0†	4.0+
No load	2.1	2.7†	2.7++
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070" restriction	45-70	45-70	45-70
Minimum	35	35	35
Fuel spill (gpm) - minimum at no-load:			
.070" restriction	0.6	0.6	0.6
Fuel pump suction at pump inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0

	2200 rpm	2500 rpm	2800 rpm
Cooling System			
Coolant temperature (degr. F.) - normal	160-185	160-185	160-185
Raw water pump:			
Inlet restriction (inches mercury) - max.	5.0†	5.0†	5.0
Outlet pressure (psi) - max.	10.0†	10.0†	10.0
Keel cooler pressure drop (psi)			
Maximum through system	6.0†	6.0†	6.0
Compression			
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm 480			
Minimum - at 600 rpm 430			

*The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be 10° lower than the oil pan temperature.

†Maximum when this is the full-load engine speed.

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "run-in" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160° - 185°F.) should be maintained throughout the run-in.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 10°F. higher than the water inlet temperature. Though a 10° rise across an engine is recommended, it has been found that a 15° temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow; therefore, be sure they are in place and fully operative or the engine will overheat during the run-in. However, if the dynamometer has a water stand-pipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

The *Basic Run-In Horsepower Schedule* is shown in the Table. The horsepower shown in the table is at SAE conditions: dry air density .0705 lb/cu. ft., air temperature of 85°F., and 500 ft. elevation.

DYNAMOMETER TEST AND RUN-IN PROCEDURES

The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the *Basic Engine Run-In Schedule.* The following items are included on the basic engine: blower, fuel pump, fresh water pump and governor. The fan and battery-charging generator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the *Engine Test Report.* The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of

BASIC RUN-IN HORSEPOWER SCHEDULE*

RPM	Time				4-Valve Head				
					3-53				
1800	10 Min.				15				
2200	1/2 Hr.				64				

Final run-in (within 5% of Rated BHP) should be for 1 1/2 hours at

2800 rpm for all other 4-Valve) cylinder

head engines.

N45 Injectors Only

power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb-ft) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

BHP = (T x RPM)/5250

Where:

BHP = brake horsepower
T = torque in lb-ft
RPM = revolutions per minute

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample on page 4).

Instrumentation

Certain instrumentation is necessary so that data required to complete the *Engine Test Report* may be obtained. The following list contains both the minimum amount of instructions and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

c. Adaptor for connecting a pressure gage or mercury manometer to the engine air box.

d. Water temperature gage installed in the thermostat housing.

e. Adaptor for connecting a pressure gage or water manometer to the crankcase.

f. Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

g. Adaptor for connecting a vacuum gage or water manometer to the blower inlet.

h. Adaptor for connecting a fuel pressure gage to the fuel manifold inlet passage.

i. Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water = psi x 27.7"
Inches of mercury = psi x 2.04"

NOTE: Before starting the Run-In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation for Starting Engine First Time* in Section 13.1.

Run-In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report*.

A. PRE-STARTING

1. Fill the lubrication system as outlined under *Lubricating System -- Preparation for Starting Engine First Time* in Section 13.1.

2. Prime the fuel system as outlined under *Fuel System -- Preparation for Starting Engine First Time* in Section 13.1.

3. A preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* in Section 14.1.

4. A preliminary injector timing check must be made before starting the engine. See *Timing Injector* in Section 14.2.

5. Preliminary governor adjustments must be made as outlined in Section 14.

6. Preliminary injector rack adjustment must be made -- see Section 14.

B. BASIC ENGINE RUN-IN

The operator should be observant at all times, so that any malfunction which may develop will be detected. Since the engine has just been reconditioned, this run-in will be a test of the workmanship of the serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc are open. Also inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 lb-ft on the torque gage (or 10-15 HP on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events for the test and run-in, and to the *Basic Run-In Horsepower Schedule* which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also, refer to the *Operating Conditions* in Section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full-load speed designated for the run-in. If a governor is encountered which cannot be adjusted to this speed, a stock governor should be installed for the run-in.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the *Basic Run-In Horsepower Schedule.*

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on the *Engine Test Report.*

Run the engine at each speed and rating for the length of time indicated in the *Basic Run-In Horsepower Schedule.* This is the Basic Run-In. During this time engine performance will improve as new parts begin to "seat in". Record all of the required data.

C. BASIC RUN-IN INSPECTION

While the engine is undergoing the Basic Run-In, check each item indicated in Section "C" of the *Engine Test Report.* Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run-In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run-In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN-IN

The primary purpose of this inspection is to provide a fine engine tune-up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tune-up procedure. Refer to Section 14.

E. FINAL RUN-IN

After all of the tests have been made and the *Engine Test Report* is completed through Section "D", the engine is ready for final test. This portion of the test and run-in procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut-down for one hour or longer, it will be necessary to have a warm-up period of 10 minutes at the same speed and load used for warm-up in the Basic Run-In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run-In, the entire Basic Run-In must be repeated as though the run-in and test procedure were started anew.

All readings observed during the Final Run-In should fall within the range specified in the *Operating Conditions* in Section 13.2, and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine *water temperature* should be taken during the last portion of the Basic Run-In at full load. It should be recorded and should be within the specified range.

ENGINE TEST REPORT

Date ______________________ Unit Number ______________________

Repair Order Number ______________________ Model Number ______________________

A PRE-STARTING

1. PRIME LUB. OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST EXHAUST VALVES	4. TIME INJECTORS	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B BASIC ENGINE RUN-IN

TIME AT SPEED	TIME START	TIME STOP	RPM	BHP	WATER TEMP.	LUB. OIL PRESS.

C BASIC RUN-IN INSPECTION

1. Check oil at rocker mechanism	
2. Inspect for lubricating oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D INSPECTION AFTER BASIC RUN-IN

1. Tighten Cylinder Head & Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E FINAL RUN-IN

TIME START	TIME STOP	TOP RPM NO-LOAD	TOP RPM FULL LOAD	BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN. F/L	WATER TEMP. FULL LOAD	LUB. OIL TEMP. F/L	LUB. OIL PRESSURE FULL LOAD	LUB. OIL PRESSURE IDLE	IDLE SPEED

F INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings		6. Replace Lubricating Oil Filter Elements	
2. Inspect Blower		7. Tighten Flywheel Bolts	
3. Check Generator Charging Rate		8. Rust Proof Cooling System	
4. Wash Oil Pan, Check Gasket		9.	
5. Clean Oil Pump Screen, Remove Cloth		10.	

REMARKS:

Final Run OK'd ______________ Dynamometer ______________ Date ______________

NOTE: Operator must initial each check and sign this report.

The *lubricating oil temperature* reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The *lubricating oil pressure* should be recorded in psi after being taken at engine speeds indicated in the *Operating Conditions*, Section 13.2.

The *fuel oil pressure* at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine rpm during the Final Run-In.

Check the *air box pressure* while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0-15 psi) or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the *crankcase pressure* while the engine is operating at maximum run-in speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the run-in indicating that new rings are beginning to "seat-in".

Check the *air inlet restriction* with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4" pipe tapped hole in the engine air inlet housing. If a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use.

The restriction at this point should be checked at a specific engine speed. Then, the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air intake vacuum at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* in section 13.2. Record these readings on the *Engine Test Report*.

Check the *exhaust back pressure* at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not provide a 1/8" pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold.

Install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. The manometer check should produce a reading in inches that is below the *Maximum Exhaust Back Pressure* for the engine (refer to Section 13.2).

Refer to the *Basic Run-In Horsepower Schedule* and determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run-In. Apply the load thus determined to the dynamometer.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run-In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run-In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run-In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run-In is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final Run-In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rust-proofing the fuel system as outlined in Section 15.3. Also, a rust inhibitor should be introduced into the cooling system (refer to Section 13.3).

DETROIT DIESEL FUEL OIL SPECIFICATIONS

Detroit Diesel designs, develops, and manufacturers commercial diesel engines to operate on diesel fuels classified by the A.S.T.M. as Designation D-975 (grades 1-D and 2-D). These grades are very similar to grades DF-1 and DF-2 of Federal Specification VV-F-800. Residual fuels and furnace oils, generally, are not considered satisfactory for Detroit Diesel engines. In some regions, however, fuel suppliers may distribute one fuel that is marketed as either diesel fuel (A.S.T.M. D-975) or domestic heating fuel (A.S.T.M. D-396) sometimes identified as furnace oil. In this case, the fuel should be investigated to determine whether the properties conform with those shown in the FUEL OIL SELECTION CHART, presented in this specification.

The FUEL OIL SELECTION CHART also will serve as a guide in the selection of the proper fuel for various applications. The fuels used must be clean, completely distilled, stable, and non-corrosive. DISTILLATION RANGE, CETANE NUMBER, and SULFUR CONTENT are three of the most important properties of diesel fuels that must be controlled to insure optimum combustion and minimum wear. Engine speed, load, and ambient temperature influence the selection of fuels with respect to distillation range and cetane number. The sulfur content of the fuel must be as low as possible to avoid excessive deposit formation, premature wear, and to minimize the sulfur dioxide exhausted into the atmosphere.

To assure that the fuel you use meets the required properties, enlist the aid of a reputable fuel oil supplier. The responsibility for clean fuel lies with the fuel supplier as well as the operator.

During cold weather engine operation, the cloud point (the temperature at which wax crystals begin to form in diesel fuel) should be 10° F below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

At temperatures below −20° F, consult an authorized Detroit Diesel service outlet, since particular attention must be given to the cooling system, lubricating system, fuel system, electrical system, and cold weather starting aids for efficient engine starting and operation.

STATEMENT OF POLICY ON FUELS AND LUBRICANTS

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpts have been taken from a policy statement of General Motors Corporation:

"It has been and continues to be General Motors policy to build motor vehicles that will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets. It is accordingly contrary to the policy of General Motors to recommend the regular and continued use of supplementary additives in such fuels and lubricants.

"This policy should not be confused with the fact that certain supplementary additives may effectively and economically solve specific operating problems which occasionally arise in some vehicles. In such instances, supplementary additives may be developed on the basis of suitable tests to remedy such problems without otherwise causing harm to vehicles. These selected products are then given official GM part numbers and made available for use in appropriate service applications.

"While General Motors Corporation assumes responsibility for the additives selected by it to remedy specific operating problems, it cannot, of course, accept responsibility for the many other additives which are constantly being marketed."

Although the stated Corporation policy is self-explanatory, the following is emphasized: Detroit Diesel does not recommend or support the use of any supplementary fuel or lubricant additives. These include all products marketed as fuel conditioners, smoke suppressants, masking agents, reodorants, tune-up compounds, top oils, break-in oils, graphitizers and friction reducing compounds.

NOTE: The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's fuel or lubricating recommendations indicated above may not be within the coverage of the warranty.

FUEL OIL SELECTION CHART

Typical Application	General Fuel Classification	Final Boiling Point	Cetane No.	Sulfur Content
		(Max)	(Min)	(Max)
All Other Applications	Winter No. 2-D Summer No. 2-D	675° F 675° F	45 40	0.50% 0.50%

NOTE: When prolonged idling periods or cold weather conditions below 32° F are encountered, the use of lighter distillate fuels may be more practical. The same consideration must be made when operating at altitudes above 5,000 ft.

DETROIT DIESEL LUBRICATING OIL SPECIFICATIONS

OIL QUALITY

OIL QUALITY is the responsibility of the oil supplier. (The term oil supplier is applicable to refiners, blenders, and rebranders of petroleum products, and does not include distributors of such products).

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The selection of a suitable lubricant in consultation with a reliable oil supplier, observance of his oil drain recommendations (based on used oil sample analysis and experience) and proper filter maintenance, will provide the best assurance of satisfactory oil performance.

Detroit Diesel lubricant recommendations are based on general experience with current lubricants of various types and give consideration to the commercial lubricants presently available.

RECOMMENDATION

Detroit Diesel engines have given optimum performance and experienced the longest service life with the following oil performance levels having the ash and zinc limits shown:

Former Military and Commercial Lube Identification	New API Letter Code Service Classification	SAE Grade †
MIL-L-2104B 1964 MS Supplement 1	CC SC CB	30 or 40 30 or 40

† SAE 30 and 40 grades have both performed satisfactorily in Detroit Diesel engines. Obviously, the expected ambient temperatures and engine cranking capability must be considered by the engine owner/operator when selecting the proper grade of oil.

ASH LIMIT
The sulfated ash limit (A.S.T.M. D-874) of the above lubricants shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.500% by weight is allowed. The majority of lubricants marketed under the performance levels shown above have a sulfated ash content between 0.55 to 0.85% by weight.

ZINC CONTENT
The zinc content, as zinc diorganodithiophosphate, shall be a minimum of 0.07% by weight.

RECOMMENDATIONS REGARDING THE USE OF CURRENT OIL PERFORMANCE LEVEL PRODUCTS MEETING PRESENT MILITARY LUBRICANT SPECIFICATIONS

The petroleum industry is currently marketing engine crankcase oils that may be identified as follows:

Military or Commercial Identification	API Letter Code Service Classification	Comment on Application and Performance
MIL-L-2104C	CD/SC	Supersedes MIL-L-45199B (Series 3) intended for diesel service.
MIL-L-46152	CC/SE	Supersedes MIL-L-2104B intended for gasoline engine passenger cars.
Universal	Numerous	Meets the performance criteria of all industry accepted tests and all current military specifications including MIL-L-2104C and MIL-L-46152.

Detroit Diesel does not have sufficient experience with any of the above described lubricants to recommend their use. Some oil suppliers have reported satisfactory performance of the above identified products marketed by them. If an owner/operator intends to use any of the above described products, it is recommended he obtain evidence from the oil supplier that the lubricant has performed satisfactorily in Detroit Diesel engines. The above products may be satisfactory for use in Detroit Diesel engines under the following conditions:

1. The sulfated ash (A.S.T.M. D-874) limit of the above lubricants shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.500% by weight is allowed.
2. The zinc content, as zinc diorganodithiophosphate, shall be a minimum of 0.07% by weight.
3. Sufficient evidence of satisfactory performance in Detroit Diesel engines has been provided to Detroit Diesel and/or the customer.

LUBRICANTS NOT RECOMMENDED

The following lubricants are NOT recommended because of a history of poor performance in Detroit Diesel engines:

Military or Commercial Identification	API Letter Code Service Classification	Comment on Performance
MIL-L-2104B/1968 MS	CC/SD	Excessive ash deposits formed
MIL-L-45199B (Series 3)	CD	Excessive ash deposits formed
Multigrade oils	Numerous	History of poor performance in most heavy duty diesel engines

COLD WEATHER OPERATION

Cold weather starting will be facilitated when immersion type electrical coolant heaters can be used. Other practical considerations, such as the use of batteries, cables and connectors of adequate size, generators or alternators of ample capacity, proper setting of voltage regulators, ether starting aids, oil and coolant heater systems, and proper fuel selection will accomplish starting with the use of SAE 30 or SAE 40 oils. For complete cold weather starting information, consult an authorized Detroit Diesel service outlet. Ask for Engineering Bulletin No. 38 entitled: "Cold Weather Operation"

NORTH SLOPE & OTHER EXTREME SUB-ZERO OPERATIONS

Some new special arctic lubricants have recently been developed for Military use in extremely cold climates. The oils that have shown best cold temperature performance may be described as multigrades having a synthetic base stock and low volatility characteristics. At this time a new Military arctic oil specification is being developed. The good oil performers have passed the oil performance criteria defined in (tentative) Federal Test Method 354 of Federal Test Standard 791. The lubricants may be used where continuous sub-zero temperatures prevail and where engines are shut down for periods longer than eight (8) hours. These are not comparable to the performance of SAE 30 or 40 oils at operating conditions and should be considered only as a last resort when engine cranking is a severe problem and auxiliary heating aids are not available.

OIL CHANGES

The oil change period is dependent on the operating conditions (e.g. load factor, etc.) of an engine that will vary with the numerous service applications. It is recommended that new engines be started with 150 hour oil change periods. For highway vehicles this corresponds to approximately 4,500 miles, and for "city" service vehicles, approximately 2,500 miles. The drain interval may then be gradually increased, or decreased with experience on a specific lubricant while also considering the recommendations of the oil supplier (analysis of the drained oil can be helpful here) until the most practical oil drain period for the particular service has been established.

Solvents should not be used as flushing oils in running engines. Dilution of the fresh refill oil supply can occur, which may be detrimental.

Full flow oil filtration systems have been used in Detroit Diesel engines since they have been manufactured. For the best results, the oil filter element should be replaced each time the oil is changed.

NEW ENGINE OIL CLASSIFICATION SYSTEM

A relatively new engine oil classification system has been introduced to industry that describes the criteria required to meet each performance level. A simplified cross-reference of oil and current commercial and military specifications is shown below.

CROSS-REFERENCE OF LUBE OIL CLASSIFICATION SYSTEMS

API Code Letters	Comparable Military or Commercial Industry Spec.
CA	MIL-L-2104A
CB	Supplement 1
CC	MIL-L-2104B (see Note 1 below)
CD	MIL-L-45199B (Series 3)
‡	MIL-L-46152 (supersedes MIL-L-2104B for Military only)
■	MIL-L-2104C (supersedes MIL-L-45199B for Military only)
SA	none
SB	none
SC	1964 MS oils – Auto passenger car
SD	1968 MS oils – Auto passenger car
SE	1972 MS oils – Auto passenger car

NOTE 1: MIL-L-2104B Lubricants are currently marketed and readily available for Commercial use. MIL-L-2104B oils are obsolete for Military service applications only.

‡ Oil performance meets or exceeds that of CC and SE oils.
■ Oil performance meets or exceeds that of CD and SC oils.

For complete descriptions, consult the following publications:

1. Society of Automotive Engineers (SAE) Technical Report J-183a.
2. Federal Test Method Standard 791a.

PUBLICATION AVAILABLE SHOWING COMMERCIAL "BRAND" NAME LUBRICANTS

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled, "EMA Lubricating Oils Data Book for Heavy Duty Automotive and Industrial Engines." The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION
111 EAST WACKER DRIVE
CHICAGO, ILLINOIS 60601

ENGINE COOLANT

Engine coolant is considered as any solution which is circulated through the engine to provide the means for heat transfer from the various engine components. In general, water containing various materials in solution is used for this purpose.

The function of the coolant is basic in the design and the successful operation of the engine and must be carefully selected and properly maintained.

COOLANT REQUIREMENTS

A suitable coolant solution must meet the following five basic requirements:

1. Provide for adequate heat transfer.

2. Provide a corrosion resistant environment within the cooling system.

3. Prevent formation of scale or sludge deposits in the cooling system.

4. Be compatible with the cooling system hose and seal materials.

5. Provide adequate freeze protection during cold weather operation.

Normally requirements 1 through 4 are satisfied by combining a suitable water with reliable inhibitors. When operating conditions dictate the need for freeze protection, a solution of suitable water and an ethylene glycol type antifreeze containing adequate inhibitors will provide a satisfactory coolant.

WATER

Any water, whether of drinking quality or not, will produce a corrosive environment in the cooling system. Also, scale deposits may form on the internal surfaces of the cooling system due to the mineral content of the water. Therefore, water selected as a coolant must be properly treated with inhibitors to control corrosion and scale deposition.

To determine if a particular water is suitable for use as a coolant when properly inhibited, the following characteristics must be considered. The concentration of (1) chlorides, (2) sulfates, (3) total hardness and (4) dissolved solids. These materials are objectionable for a number of reasons: chlorides and/or sulfates will accelerate corrosion, while hardness (percentage of magnesium and calcium present) will cause deposits of scale. Total dissolved solids may cause scale deposits, sludge deposits, corrosion or a combination of these. Chlorides, sulfates, magnesium and calcium are among but not necessarily all the materials which make up dissolved solids. Water, within the limits specified in Tables 1 and 2, Figure A, is satisfactory as an engine coolant when proper inhibitors are added.

CORROSION INHIBITORS

A corrosion inhibitor is a water soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites and soluble oil. Depletion of all types of inhibitors occur through normal operation and therefore strength levels must be maintained by the addition of inhibitors at prescribed intervals.

CHROMATES: Sodium chromate and potassium dichromate are two of the more commonly used *water* system corrosion inhibitors. However, the restrictive use of these materials, due to ecology considerations, has de-emphasized their use in favor of non-chromates. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors must *not* be used in ethylene glycol antifreeze solutions. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with permanent type antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate, and will result in engine overheating. Engines which have operated with a chromate inhibited water must be chemically cleaned before the addition of ethylene glycol type antifreeze. A commercial heavy duty descaler should be used in accordance with the manufacturer's recommendation for this purpose.

SOLUBLE OIL: Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if the concentration exceeds 1% by volume. For example: 1-1/4% of soluble oil in the cooling system increases fire deck temperatures 6% and a 2-1/2% concentration raises fire deck temperature up to 15%. Soluble oil *must not be used* as a corrosion inhibitor.

NON-CHROMATES: Non-chromate inhibitors (borates, nitrates, nitrites, etc.) provide corrosion

TABLE 1

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

Refer to Table 2 for evaluation of water intended for use in a coolant solution.

TABLE 2

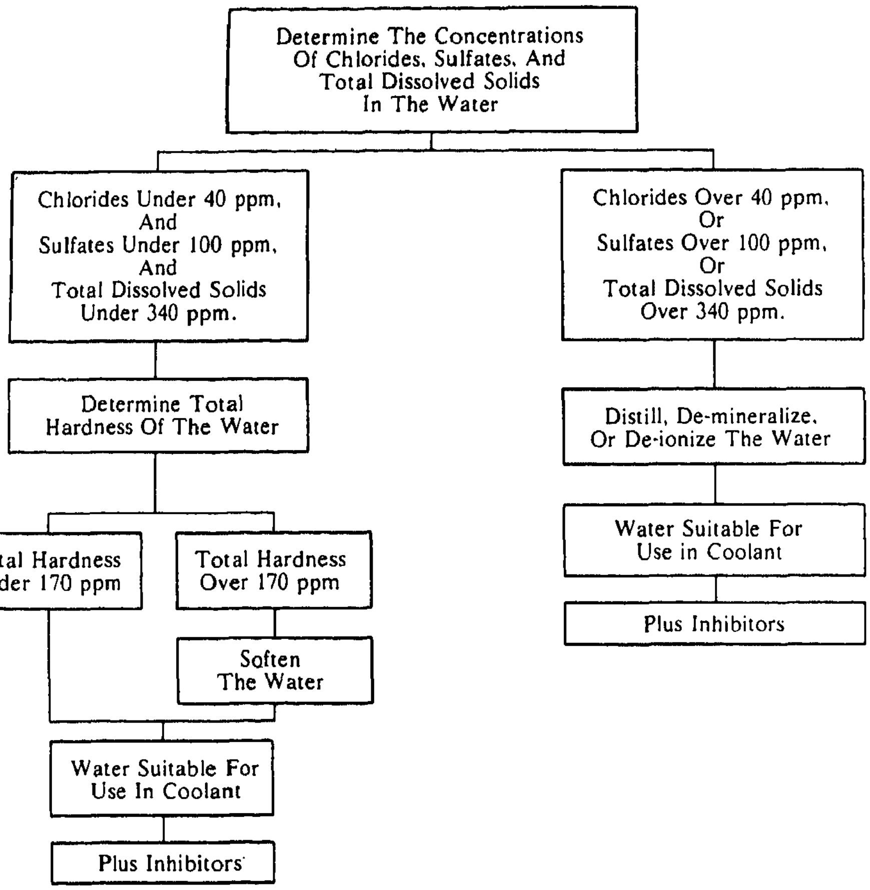


Figure A

protection in the cooling system with the basic advantage that they can be used with either water or a water and ethylene glycol solution.

INHIBITOR SYSTEMS

ı is considered as a combination of chemical compounds which provide corrosion protection, pH control and water softening ability. Corrosion protection has been discussed earlier under the section on *Corrosion Inhibitors*. The pH control is used to maintain an acid free solution. The water softening ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant

COOLANT INHIBITOR CHART

Inhibitor or Inhibitor System	Corrosion Inhibitor Type	Complete Inhibitor System	Inhibitor Compatability Water	Inhibitor Compatability Ethylene Glycol Base Antifreeze
Sodium chromate	*Chromate	No	Yes	No
Potassium dichromate	*Chromate	No	Yes	No
Perry filter elements				
5020 (Type OS)	*Chromate	Yes	Yes	No
S-453 (Spin on)	*Chromate	Yes	Yes	No
5030 (Type OS)	@Non-chromate	Yes	Yes	Yes
S-331 (Spin on)	@Non-chromate	Yes	Yes	Yes
5070 (Type OS)	# Non-chromate	Yes	Yes	Yes
S-473 (Spin on)	# Non-chromate	Yes	Yes	Yes
Lenroc filter element	Non-chromate	Yes	Yes	Yes
Fleetguard filter elements				
DCA (Canister)	Non-chromate	Yes	Yes	Yes
DCA (Spin on)	Non-chromate	Yes	Yes	Yes
AC Filter elements				
DCA (Canister)	Non-chromate	Yes	Yes	Yes
DCA (Spin on)	Non-chromate	Yes	Yes	Yes
Luber-Finer filter elements				
LW-4739 (Canister)	Non-chromate	Yes	Yes	Yes
LFW-4744 (Spin on)	Non-chromate	Yes	Yes	Yes
Nalcool 2000 (Liquid)	Non-chromate	Yes	Yes	Yes
Liquid Perry (LP-20)	Non-chromate	Yes	Yes	Yes
Lubercool (Liquid)	Non-chromate	Yes	Yes	Yes

@Note 1 - Perry "Year Around" formula.
Note 2 - Perry "Universal" formula.

Figure B

filter elements, liquid and dry bulk inhibitor additives and as an integral part of permanent antifreeze.

COOLANT FILTER ELEMENTS: Replaceable elements are available with various chemical inhibitor systems. Care should be used in the selection of elements relative to inhibitor compatibility with coolant solutions shown in Figure B.

Problems have developed from the use of the magnesium lower support plate used by some manufacturers in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical (Figure C). The use of aluminum or zinc in preference to magnesium is recommended to eliminate this type of deposit.

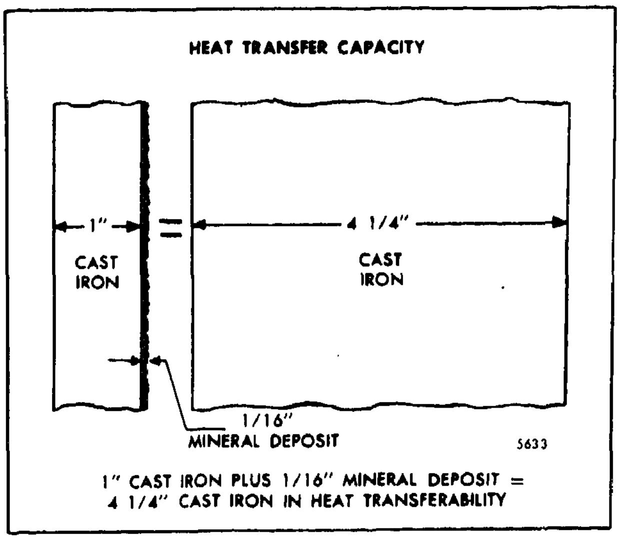


Figure C

A high chloride coolant will have a detrimental effect on the water softening capabilities of systems using ion-exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by a regenerative process caused by high chloride content solutions.

BULK INHIBITOR ADDITIVES: Commercially packaged inhibitor systems are available which can be added directly to the engine coolant or to bulk storage tanks containing coolant solution. Both chromate and non-chromate systems are available and care should be taken regarding inhibitor compatability with other coolant constituents (Figure B).

A non-chromate inhibitor system is recommended for use in Detroit Diesel engines. The non-chromate systems can be used with either water or ethylene glycol antifreeze solutions and provide corrosion protection, pH control and water softening. Some of the approved non-chromate inhibitor systems offer the additional advantage of a simple on site test to determine protection level.

ANTIFREEZE

When freeze protection is required, an ethylene glycol base permanent antifreeze should be used. An
type of antifreeze
d on initial fill
n of 30% by
% concentra-
n protection.

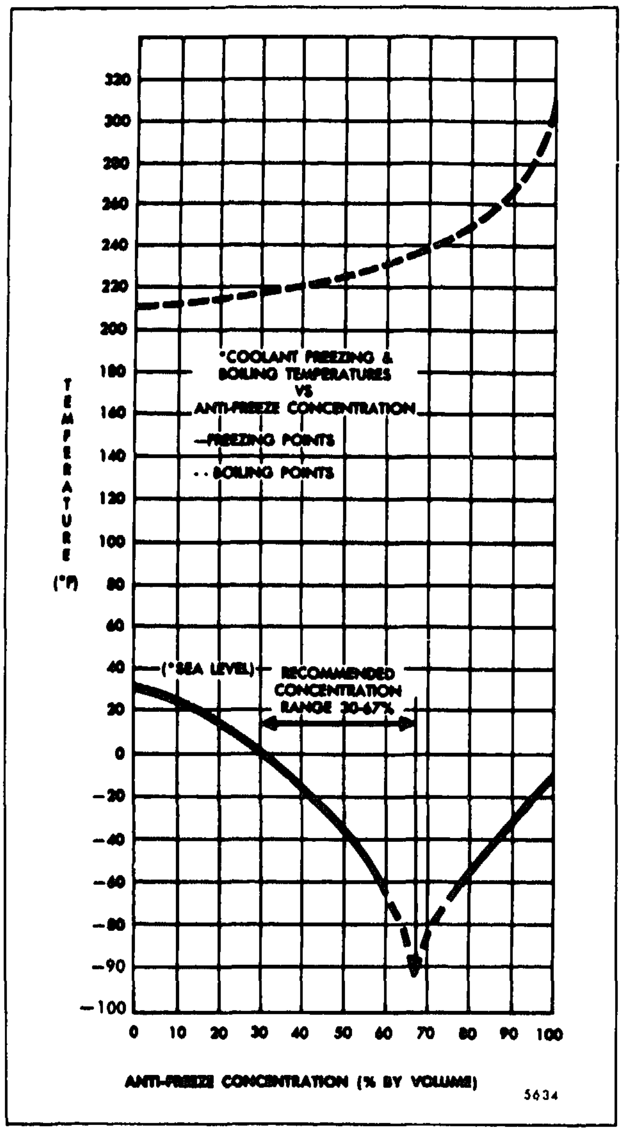


Figure D

Concentrations over 67% adversely affect freeze protection and heat transfer rates (Figure D).

Inhibitor depletion will occur in ethylene glycol base antifreeze through normal service. The inhibitors must be replenished at approximately 500 hour or 20,000 mile intervals with a non-chromate inhibitor system. Commercially available inhibitor systems (Fig. B) may be used to re-inhibit antifreeze solutions.

Several brands of permanent antifreeze are available with sealer additives. The specific type of sealers vary with the manufacturer. Antifreeze with sealer additives is *not* recommended for use in Detroit Diesel engines due to plugging problems throughout various areas of the cooling system.

COOLANT RECOMMENDATIONS

1. Always use a properly inhibited coolant.

2. If freeze protection is required, always use ethylene glycol antifreeze.

3. Re-inhibit antifreeze with a non-chromate inhibitor system.

4. Always follow the manufacturer's recommendations on inhibitor usage and handling.

5. Do not use soluble oil.

6. Chromate inhibitors should *never* be used with permanent antifreeze.

7. Sealer type antifreeze should *not* be used.

8. Maintain prescribed inhibitor strength.

SECTION 14

ENGINE TUNE-UP

CONTENTS

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms. governor, etc. should only be required periodically to compensate for normal wear on parts.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if the cylinder head, governor, or injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

To tune-up an engine completely, all of the adjustments are made by following the applicable tune-up sequence given below after the engine has reached the normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Tune-Up Sequence for Mechanical Governor

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the buffer screw.

NOTE: Use new valve rocker cover gasket(s) after each tune-up.

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, especially in the low speed range.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

ENGINES WITH FOUR VALVE CYLINDER HEADS

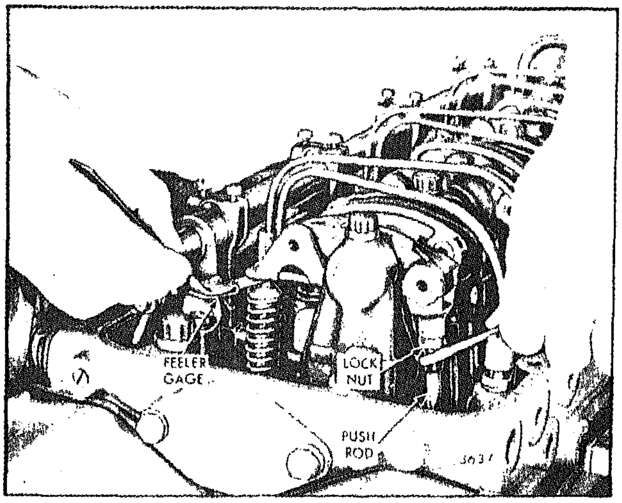


Fig. 2 - Adjusting Valve Clearance (Four Valve Head)

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Exhaust Valve Clearance Adjustment (Cold Engine)

1. Remove the loose dirt from the valve rocker cover and remove the cover.

2. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted.

CAUTION: If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a .027 " feeler gage, J 9708, between the end of one exhaust valve stem and the rocker arm bridge (Fig. 2). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16 " wrench and tighten the lock nut with a 1/2 " wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the .025 " gage will pass freely between the end of one valve stem and the rocker arm bridge and the .027 " gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

Exhaust Valve Clearance Adjustment (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance, when running at full load, may become insufficient.

1. With the engine at normal operating temperature (160 °-185 ° F.), recheck the exhaust valve clearance with feeler gage J 9708. At this time, if the valve clearance is correct, the .023 " gage will pass freely between the end of one valve stem and the rocker arm bridge and the .025 " feeler gage will not pass through. Readjust the push rod, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

FUEL INJECTOR TIMING

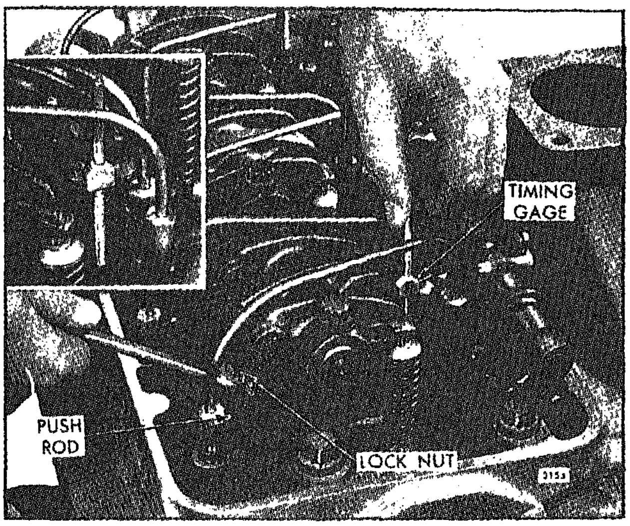


Fig. 1 - Timing Fuel Injector

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Time Fuel Injector

After the exhaust valve clearance has been adjusted (Section 14.1), time the fuel injectors as follows:

1. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

CAUTION: If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

Injector	Timing Dimension	Timing Gage
N45	1.460	J 1853

INJECTOR TIMING GAGE CHART

3. Place the small end of the injector timing gage (refer to the chart for the correct timing gage) in the hole provided in the top of the injector body, with the flat of the gage toward the injector follower (Fig. 1).

4. Loosen the injector rocker arm push rod lock nut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

6. Hold the push rod and tighten the lock nut. Check the adjustment and, if necessary, readjust the push rod.

7. Time the remaining injectors in the same manner as outlined above.

8. If no further engine tune-up is required, install the valve rocker cover, using a new gasket.

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINE

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

NOTE: Loosen the load limit lever for the load limiting device, if the engine is so equipped, before proceeding with the governor adjustment.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Remove the high speed spring retainer cover.

2. Back out the buffer screw until it extends 5/8" beyond the governor housing.

3. Clean and remove the valve rocker cover.

4. Start the engine and adjust the idle speed screw (Fig. 5) to obtain an idle speed of 500-600 rpm.

NOTE: The recommended idle speed is 500-600 rpm, but may vary with special engine applications.

5. Stop the engine and remove the governor cover.

6. Start the engine and control the speed manually by operating the injector control tube lever. The engine speed should be between 800 and 1000 rpm.

CAUTION: Do not overspeed the engine.

7. Check the gap between the low speed spring cap and the high speed spring plunger with a .0015" feeler gage. If the gap setting is incorrect, reset the gap adjusting screw (Fig. 1). If the setting is correct, the .0015" movement can be seen by placing a few drops of oil into the governor gap and pressing a screw driver against the gap adjusting screw. Movement of the cap toward the plunger will force the oil from the gap in the form of a small bead.

8. Hold the gap adjusting screw and tighten the lock nut.

9. Recheck the gap and readjust if necessary.

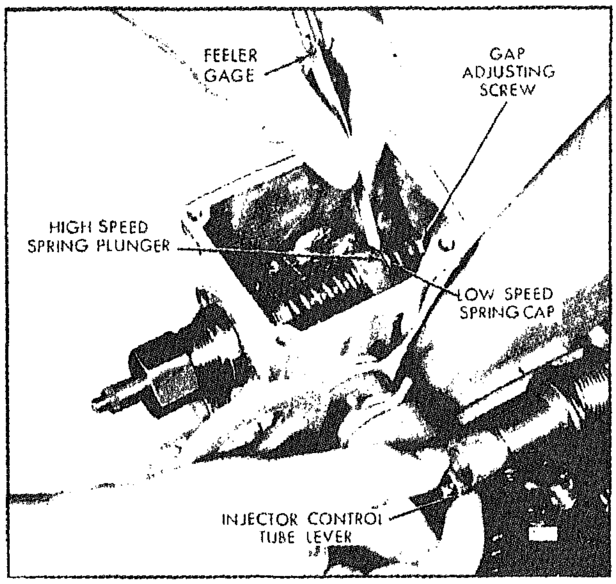


Fig. 1 - Adjusting Governor Gap

10. Install the governor cover. The governor cover should be placed on the housing with the pin of the speed control lever projecting into the slot of the differential lever.

11. Install the screws and lock washers finger tight. Pull the cover away from the engine and tighten the screws. This step will properly locate the cover on the governor housing.

Position Injector Rack Control Levers

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the speed control lever.

2. Loosen all of the inner and outer injector rack control lever adjusting screws (Fig. 2). Be sure all of the levers are free on the injector control tube.

3. Move the speed control lever to the full-fuel

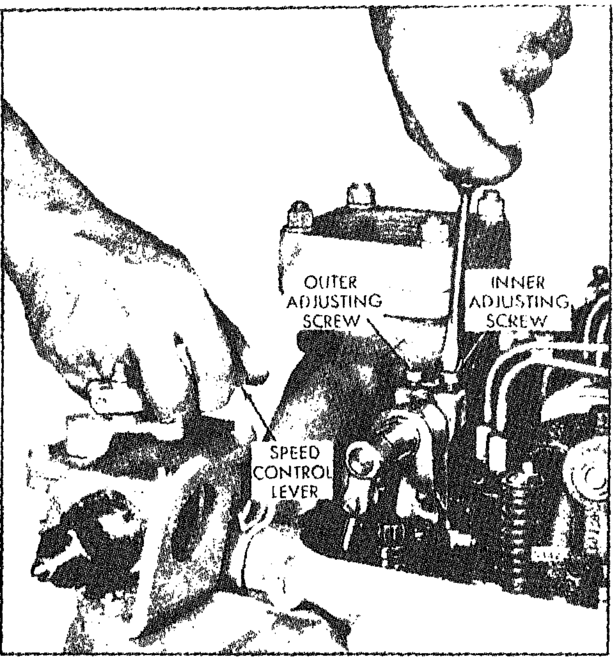


Fig. 2 - Positioning the Rear Injector Rack Control Lever

position. Turn the inner adjusting screw down on the rear injector rack control lever until a step-up in effort is noted. This will place the rear injector rack in the full-fuel position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws. This should result in placing the governor linkage and control tube assembly in the same positions that they will attain while the engine is running at full-load.

4. To be sure of proper rack adjustment, hold the speed control lever in the full-fuel position. Press down on the injector rack coupling causing the coupling to rotate.

> **NOTE:** This coupling is on the end of the injector rack and fits around the ball end of the rack control lever.

The setting is sufficiently tight if the coupling returns to its original position. If the coupling does not return to its original position, it is too loose. To correct, back off the outer adjusting screw slightly and tighten the inner adjusting screw.

The coupling is too tight if, when moving the speed control lever from the idle to the maximum speed position, the injector rack coupling becomes tight before the speed control lever reaches the end of its travel (stop under the governor cover). This will result in a step-up in effort to move the speed control lever to its maximum speed position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the coupling is found to be too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

5. Manually hold the rear injector rack control lever in the full-fuel position. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lbs.**

6. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

7. Position the remaining rack control levers as outlined in Steps 5 and 6.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine name plate, the maximum no-load speed may be set as follows:

TYPE A GOVERNOR SPRINGS (Fig. 4):

1. Loosen the lock nut (Fig. 3) and back off the high speed spring retainer approximately five turns.

2. With the engine at operating temperature and no-load on the engine, place the speed control lever in the full-fuel position. Turn the high speed spring retainer IN until the engine is operating at the recommended no-load speed.

The best method of determining the engine speed is with an accurate tachometer.

3. Hold the high speed spring retainer and tighten the lock nut.

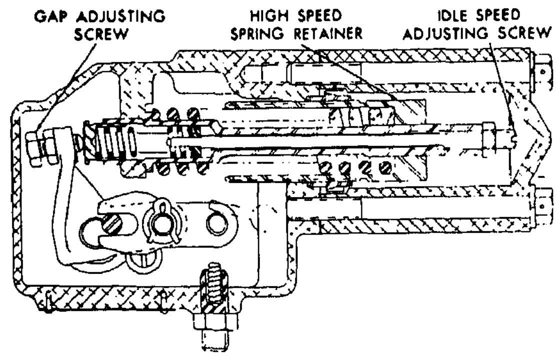


Fig. 4 · Governor Spring Assemblies

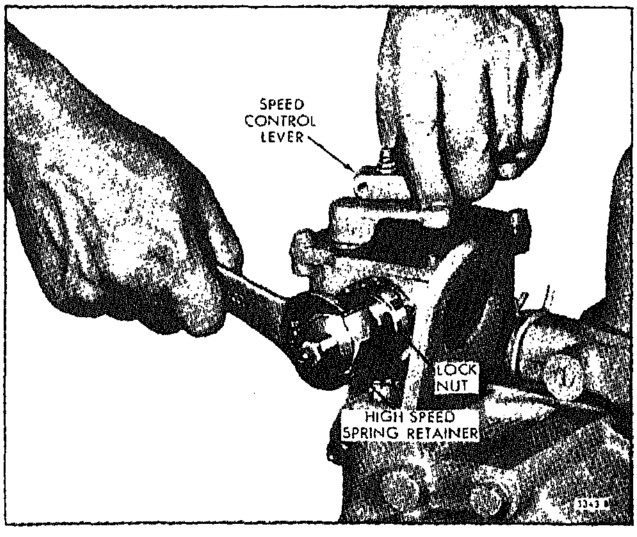


Fig. 3 · Adjusting Maximum No-Load Engine Speed

Adjust Idle Speed

With the maximum no-load speed properly adjusted, the idle speed may be adjusted as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 5) until the engine idles at the recommended idle speed.

The recommended idle speed is 500-600 rpm, but may vary with the particular engine application.

2. Hold the idle speed adjusting screw and tighten the lock nut.

3. Install the high speed spring cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating

14.3.1 Limiting Speed Governor

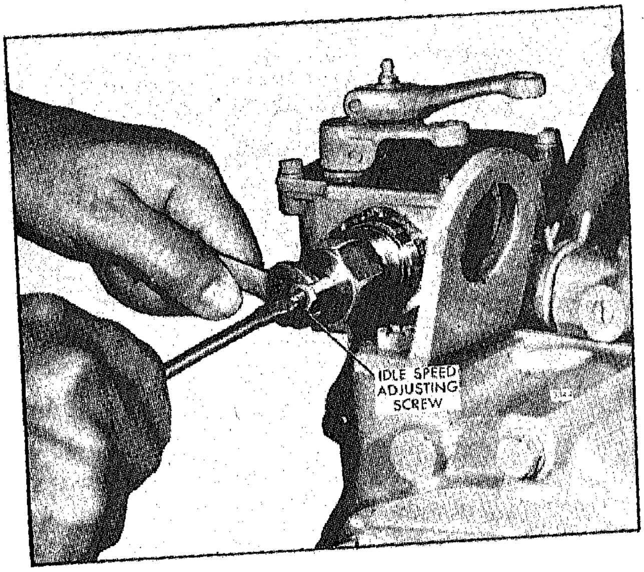


Fig. 5 - Adjusting Engine Idle Speed

temperature, loosen the lock nut and turn the buffer screw in (Fig. 6) so that it contacts the differential lever as lightly as possible and still eliminates engine roll.

NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm from the maximum speed attained in Step 1, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the lock nut.

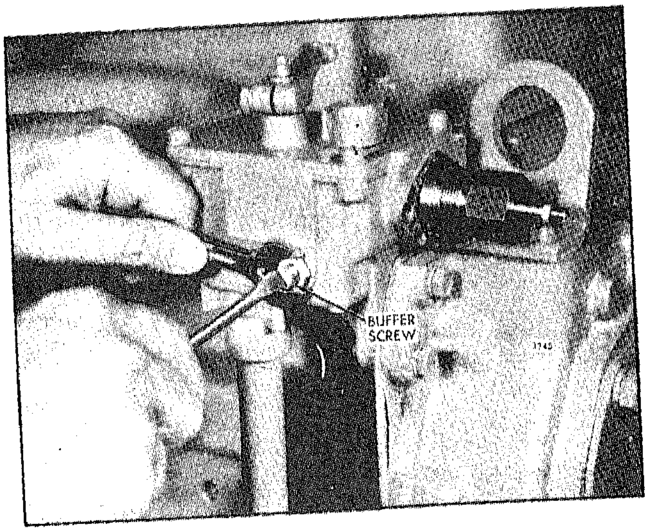


Fig. 6 - Adjusting the Buffer Screw

SECTION 15

PREVENTIVE MAINTENANCE - TROUBLE SHOOTING - STORAGE

CONTENTS

LUBRICATION AND PREVENTIVE MAINTENANCE

To obtain the best performance and long life from a Detroit Diesel engine, the Operator must adhere to the following schedule and instructions on lubrication and preventive maintenance.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions* in Section 13.

The time intervals given in the chart on the following page are actual operating hours or miles of an engine. If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and, therefore, will drain readily.

LUBRICATION AND PREVENTIVE MAINTENANCE CHART Hours	Time Interval								
		8	50	100	200	300	500	1,000	2,000
Item Operation	Daily								
1. Engine Oil	X								
2. Oil Filter*									
3. Coolant and Filter	X						X	X	
4. Hoses							X		
5. Radiator								X	
7. Raw Water Pump	X								
8. Fuel Tank	X						X		
9. Fuel Strainer and Filter						X			
10. Air Cleaner		X					X		
11. Air Box Drains							X	X	
12. Ventilating System								X	
13. Blower Screen								X	
14. Starting Motor*									
15. Battery-Charging Generator				X	X		X		X
16. Battery				X					
19. Engine Tune-Up*									
20. Drive Belts					X				
22. Fan Hub Bearings*									
23. Shut-Down System						X			

*See items on following pages

Item 1

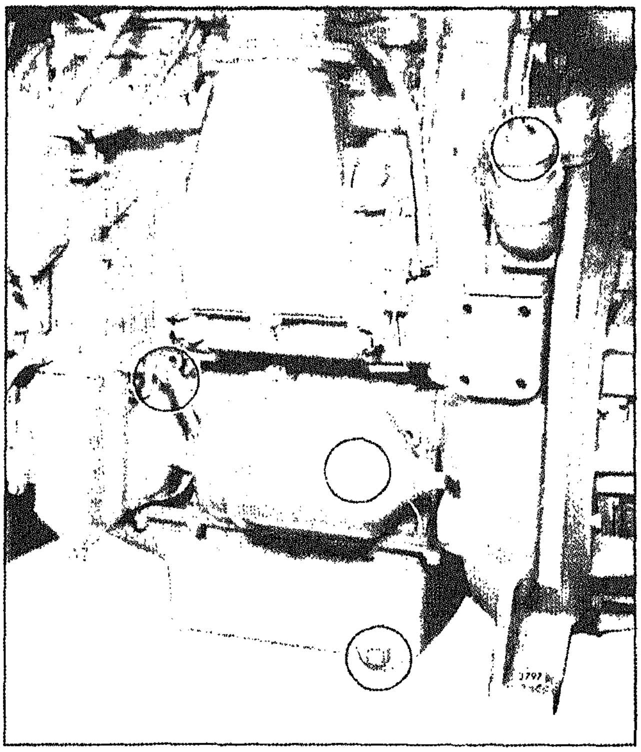
Check the oil level daily before starting the engine. Add oil, if necessary, to bring it to the proper level on the dipstick.

Select the proper grade of oil in accordance with the instructions in the *Lubricating Oil Specifications* in Section 13.3.

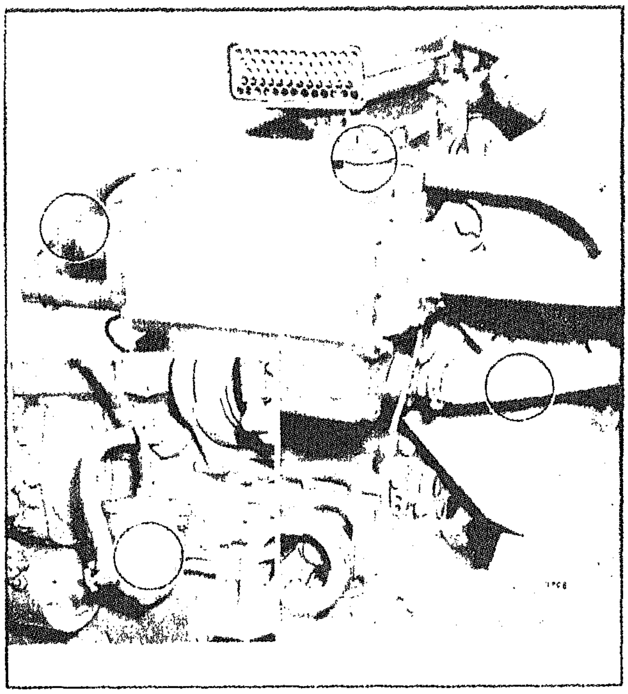
It is recommended that new engines be started with 100 hour oil change periods. For highway vehicles, this corresponds to approximately 3,000 miles, and for city-service vehicles approximately 1,000-2,000 miles. The drain interval may then be gradually increased, or decreased, following the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the oil sample analysis) until the most practical oil change period has been established.

Item 2

Change the engine oil filter elements and gaskets each time the engine oil is changed. Any deviation, such as changing filters every other oil change, should be based on a laboratory analysis of the drained oil and used filter elements to determine if such practice is practical for proper protection of the engine. Make a



Items 1 and 2



Items 3 and 4

visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

When the engine is equipped with a turbocharger, pre-lubricate it as outlined under *Install Turbocharger* in Section 3.5.

If the engine is equipped with a governor oil filter, change the element every 1,000 hours.

Item 3

Check the coolant level daily and maintain it near the top of the heat exchanger tank or the radiator upper tank.

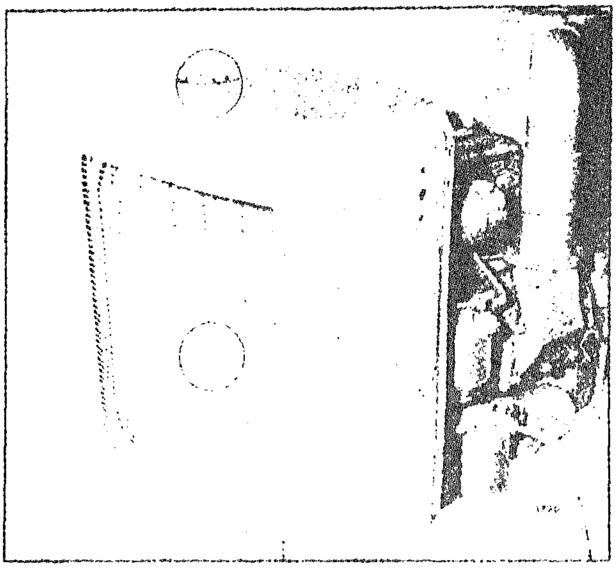
Clean the cooling system every 1,000 hours or 30,000 miles using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then fill the system with soft water, adding a good grade of rust inhibitor or a high boiling point type antifreeze (refer to *Engine Coolant* in Section 13.3). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other

deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse-flushed.

If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 500 hours or 15,000 miles.

Item 4

Inspect all of the cooling system hoses at least once every 500 hours or 15,000 miles for signs of deterioration. Replace the hoses if necessary.



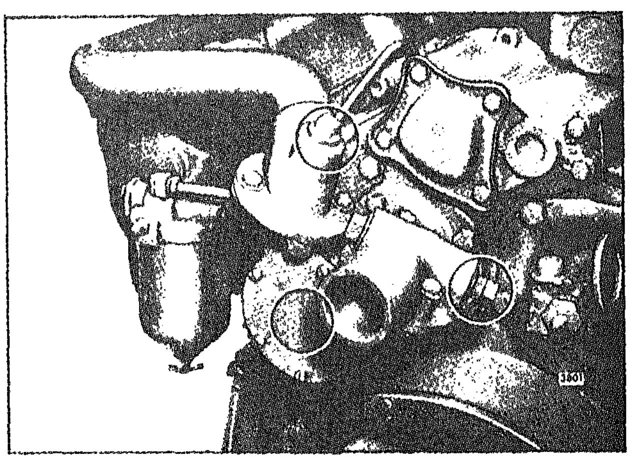
Item 5

Item 5

Inspect the exterior of the radiator core every 1,000 hours or 30,000 miles and, if necessary, clean it with a quality grease solvent such as Oleum and dry it with compressed air. *Do not use fuel oil, kerosene or gasoline.* It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Item 7

Check the prime on the raw water pump; the engine should not be operated with a dry pump. Prime the pump, if necessary, by removing the pipe plug provided in the pump inlet elbow and adding water. Reinstall the plug.



Item 7

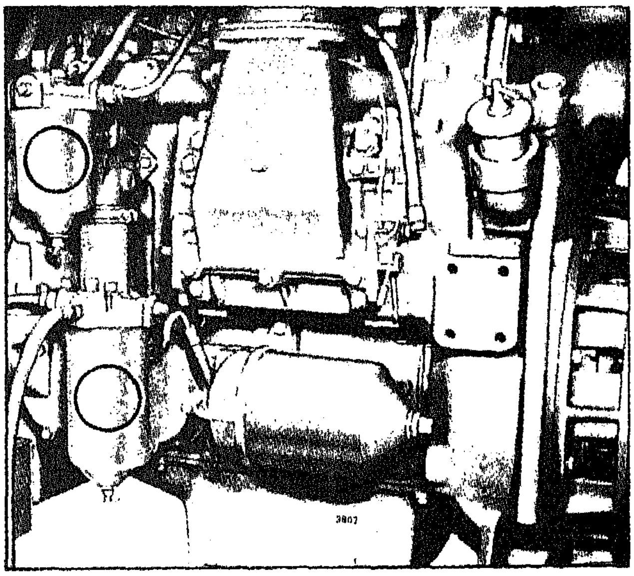
Item 8

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Diesel Fuel Oil Specifications* in Section 13.3. Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water or sediment.

Item 9

Install new elements every 300 hours or 9,000 miles or when plugging is indicated.

A method of determining when elements are plugged



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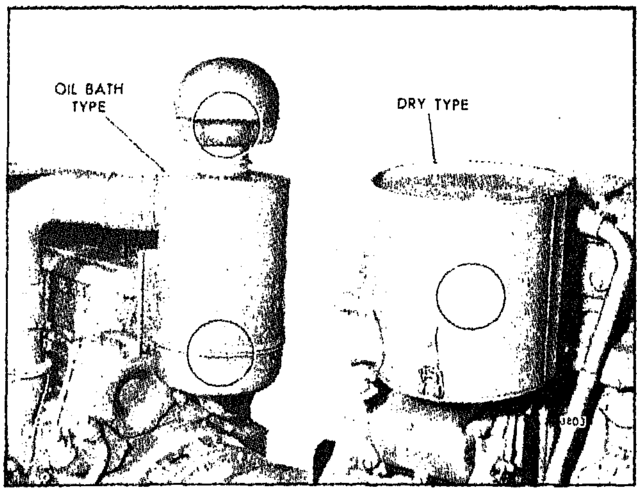


Item 10

to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury. At normal operating speeds (1800-2800 rpm), the fuel pressure is 45 to 70 psi. Change the fuel filter elements whenever the inlet restriction (suction) at the fuel pump reaches 12 inches of mercury at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to 45 psi.

Item 10

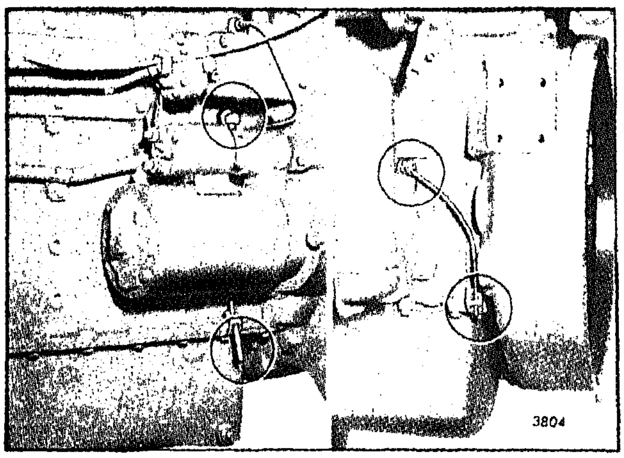
Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every 8 hours (every 6,000 miles for highway vehicle engines), or less if operating conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade and viscosity *heavy-duty* oil as used in the engine. The frequency of servicing may be varied to suit local dust conditions.

It is recommended that the body and fixed element in the heavy-duty oil bath type air cleaner be serviced every 500 hours, 15,000 miles or as conditions warrant.

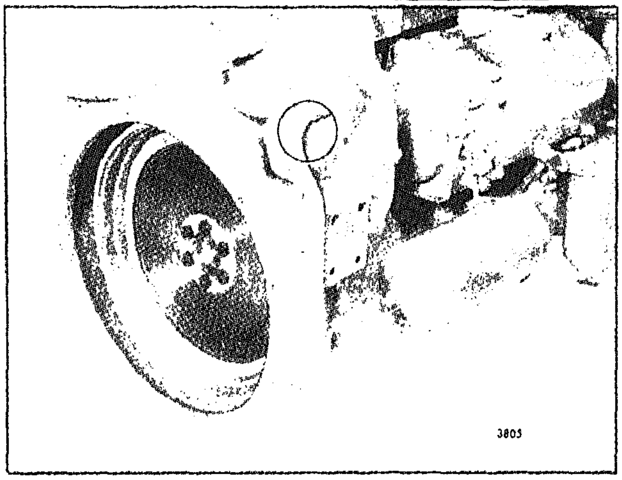
Clean or replace the element in the dry-type air cleaner when the restriction indicator instrument indicates high restriction or when a water manometer reading at the air inlet housing indicates the maximum allowable air inlet restriction (Section 13.2).

Item 11

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours or 30,000 miles. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes should be



Item 11



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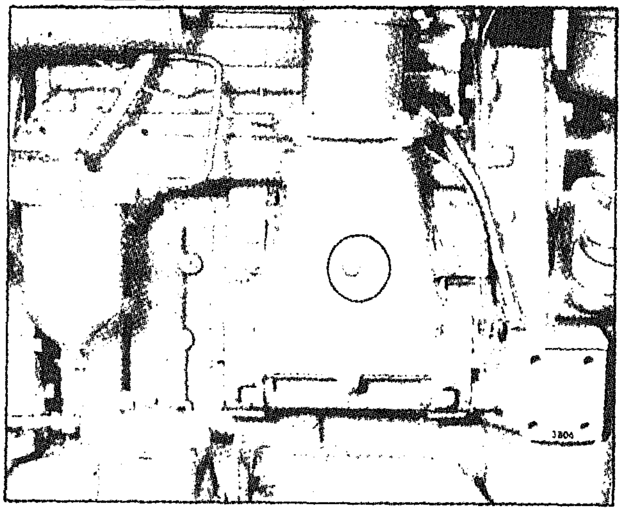


Item 13

cleaned periodically even though a clogged condition is not apparent. If the engine is equipped with an air box drain tank, drain the sediment periodically. If the engine is equipped with an air box drain check valve, replace the valve every 500 hours or 15,000 miles.

Item 12

Remove the externally mounted crankcase breather assembly every 1,000 hours or 30,000 miles and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service (refer to Section 4.8).

Clean the internally mounted breather pads at time of engine overhaul, or sooner if excessive crankcase pressure is observed.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed (refer to Section 4.8).

Item 13

Inspect the blower screen and gasket assembly every 1,000 hours or 30,000 miles and, if necessary, clean the screen in fuel oil and dry it with compressed air. Reinstall the screen and gasket assembly with the screen side of the assembly toward the blower.

Item 14

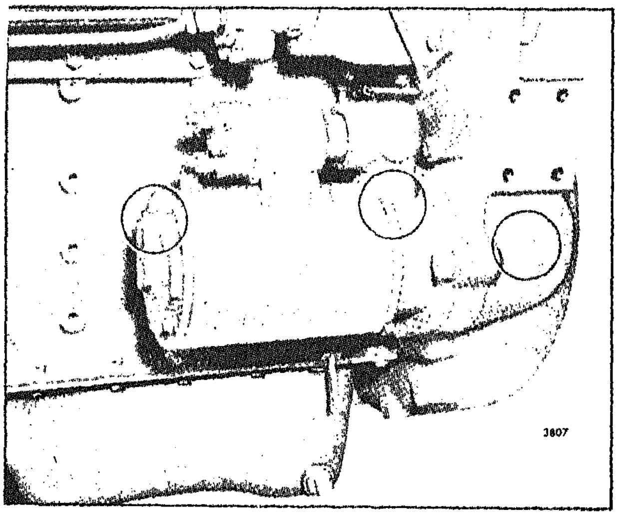
The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

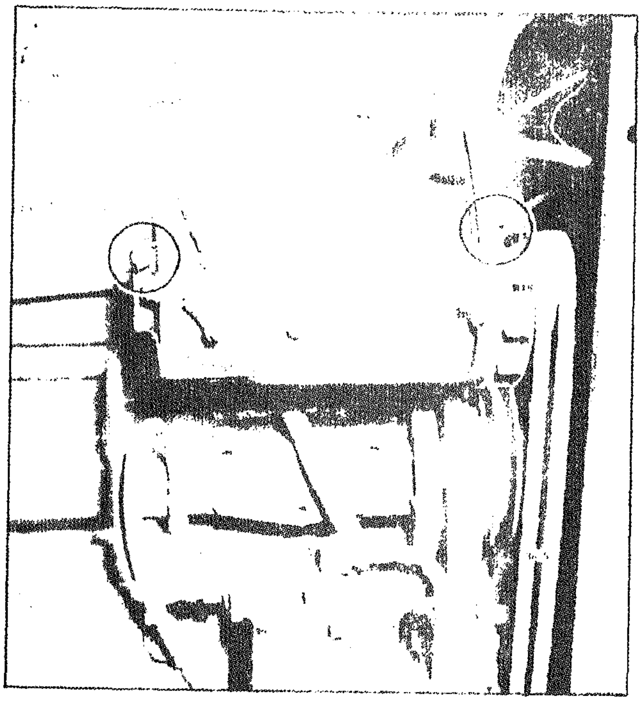
Item 15

Lubricate the battery-charging generator (alternator) bearings or bushings with 5 or 6 drops of engine oil at the hinge cap oiler every 200 hours or 6,000 miles.

On early generators equipped with grease cups, turn the cups down one full turn every 100 hours or 3,000 miles of operation. Keep the grease cups filled with



Item 14



Item 15

Delco-Remy Cam and Ball Bearing Lubricating, or equivalent. Avoid excessive lubrication since this may cause lubricant to be forced onto the commutator.

Some generators have a built-in supply of grease, while others use sealed bearings. In these latter two cases, additional lubrication is not necessary.

On D.C. generators, inspect the commutator and brushes every 500 hours or 15,000 miles. Clean the commutator every 2,000 hours or 60,000 miles, if necessary, with No. 00 sandpaper or a brush seating stone. After cleaning, reseat the brushes and blow out the dust.

On A.C. generators (alternators), the slip rings and brushes can be inspected through the end frame assembly. If the slip rings are dirty, they should be cleaned with 400 grain or finer polishing cloth. Never use emery cloth to clean slip rings. Hold the polishing cloth against the slip rings with the generator in operation and blow away all dust after the cleaning operation. If the slip rings are rough or out of round, replace them.

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

Item 16

Check the specific gravity of the electrolyte in each cell of the battery every 100 hours or 3,000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 19

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc. should only be required periodically to compensate for normal wear on parts.

Item 20

New standard V-belts will stretch after the first few hours of operation. Run the engine for 15 *seconds* to seat the belts, then retension them. Retighten new fan drive, pump drive, battery-charging generator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 240 miles of operation. Thereafter, check the tension of the drive belts every 200 hours or 6,000 miles and adjust, if necessary. Too tight a belt is destructive to the bearings of the driven part; a loose belt will slip.

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032″ of their specified center distances.

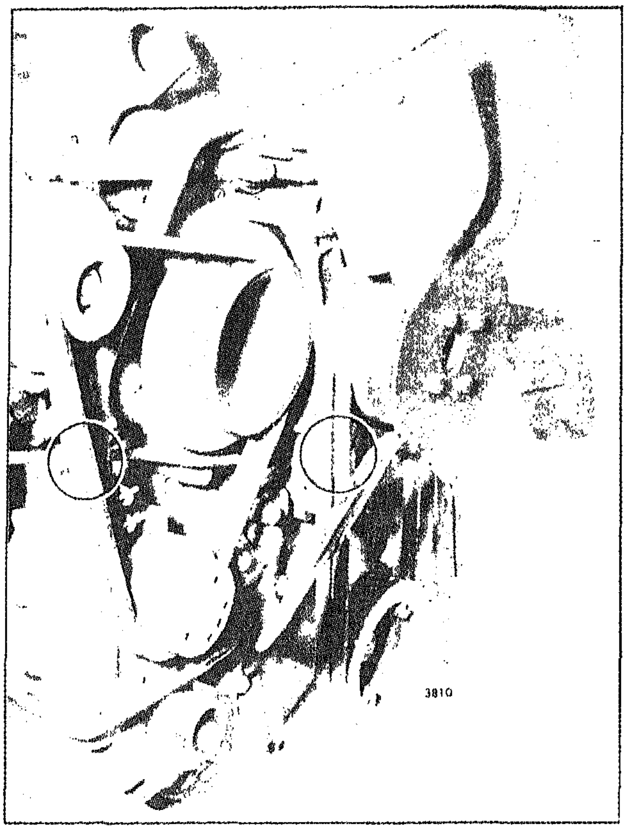
Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2″ to 3/4″. If belt tension gage BT-33-73FA or equivalent is available, adjust the belt tension as outlined in the Chart.

Engine Model	Fan Drive		Generator Drive		
	2 or 3 Belts	Single Belt	Two 3/8″ or 1/2″ Belts	One 1/2″ Belt	One Wide Belt*
2, 3, 4-53	40-50	—	40-50	50-70	40-50
6, 8V-53	60-80	80-100	40-50	50-70	40-50
All	For 3-point or triangular drive use a tension of 90-120.				

*Belt tension is 50-70 for a single premium high capacity belt (.785″ wide) used to drive a 12 cfm air compressor.

BELT TENSION CHART (lbs/belt)

NOTE: When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.



Item 20

Item 22

At a major engine overhaul, discard the bearings in the fan hub assembly used in radiator cooled engines. Pack the hub assembly, using new bearings, with Texaco Premium RB or an equivalent performance grease.

Item 23

Check the shut-down system every 300 operating hours or each month to be sure it will function when needed.

TROUBLE SHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.

2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.

2. Stop the engine and remove the valve rocker cover(s).

3. Check the valve clearance.

4. Start the engine. Then hold an injector follower down with a screw driver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

6. Provided the injector operating mechanism of the faulty cylinder is functioning satisfactorily, remove the fuel injector and install a new one.

7. If installation of a new injector does not eliminate the misfiring, check the compression pressure of the cylinder in question.

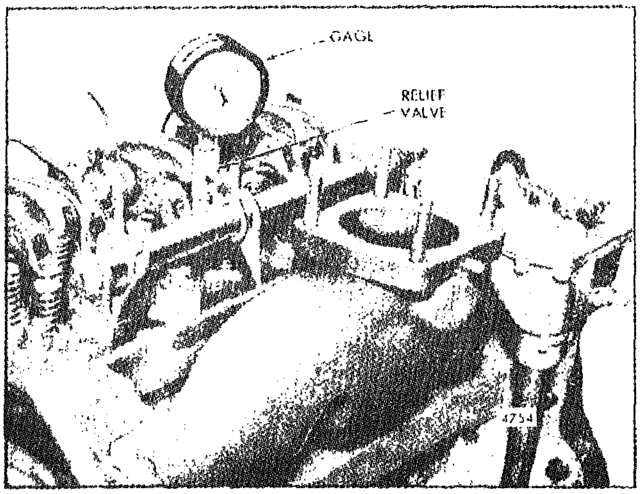


Fig. 1 · Checking Compression Pressure

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

Minimum Compression Pressure (psi) at 600 rpm		Altitude, Feet Above Sea Level
Std. Engine		
430		0
400		2,500
370		5,000
340		7,500
315		10,000

TABLE 1

2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.

3. Remove the injector and install adaptor J 7915-02 and pressure gage and hose assembly J 6992 (Fig. 1).

4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.

5. Start the engine and run it at a 600 rpm. Observe

and record the compression pressure indicated on the gage. *Do not crank the engine with the starting motor to obtain the compression pressure.*

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In additon, the variation in compression pressures between cylinders must not exceed 25 psi at 600 rpm.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool. A broken or stuck ring will not have a "spring-like" action.

B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

Engine Out of Fuel

The problem in restarting an engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons of fuel.

2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

NOTE: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in Section 2.0 under *Trouble Shooting*.

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head or end plate gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

Check the crankcase pressure with a manometer

connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the *Engine Operating Conditions* in Section 13.2.

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer. Connect the manometer to the exhaust manifold (except on turbocharged engines) by removing the 1/8 " pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32 " hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8 " pipe plug.

Check the readings obtained at various speeds (at no-load) with the *Engine Operating Conditions* in Section 13.2.

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

Check the air box pressure with a manometer connected to an air box drain tube.

Check the readings obtained at various speeds with the *Engine Operating Conditions* in Section 13.2.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2 " above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* in Section 13.2.

PROPER USE OF MANOMETER

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface

PRESSURE CONVERSION CHART

1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	.4919 psi
1" mercury	=	13.6000" water
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury

TABLE 3

and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

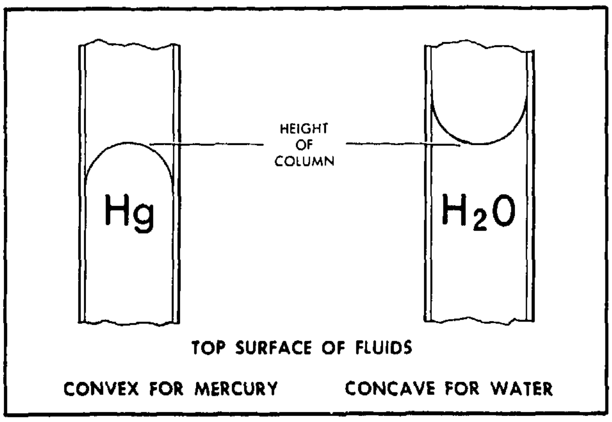


Fig. 2 - Comparison of Column Height for Mercury and Water Manometers

Refer to Table 3 to convert the manometer reading into other units of measurement.

Chart 1

EXHAUSTIVE SMOKE ANALYSIS

MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 °F.

Probable Causes

BLACK OR GREY SMOKE

Check For

1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL

BLUE SMOKE

Check For

4. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)

WHITE SMOKE

Check For

5. MISFIRING CYLINDERS

SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

2. Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

Avoid lugging the engine as this will cause incomplete combustion.

3. Check for use of an improper grade of fuel. Refer to *Fuel Oil Specifications* in Section 13.3.

4. Check for internal lubricating oil leaks and refer to the *High Lubricating Oil Consumption* chart.

5. Check for faulty injectors and replace as necessary.

Check for low compression and consult the *Hard Starting* chart.

The use of low cetane fuel will cause this condition. Refer to *Fuel Oil Specifications* in Section 13.3.

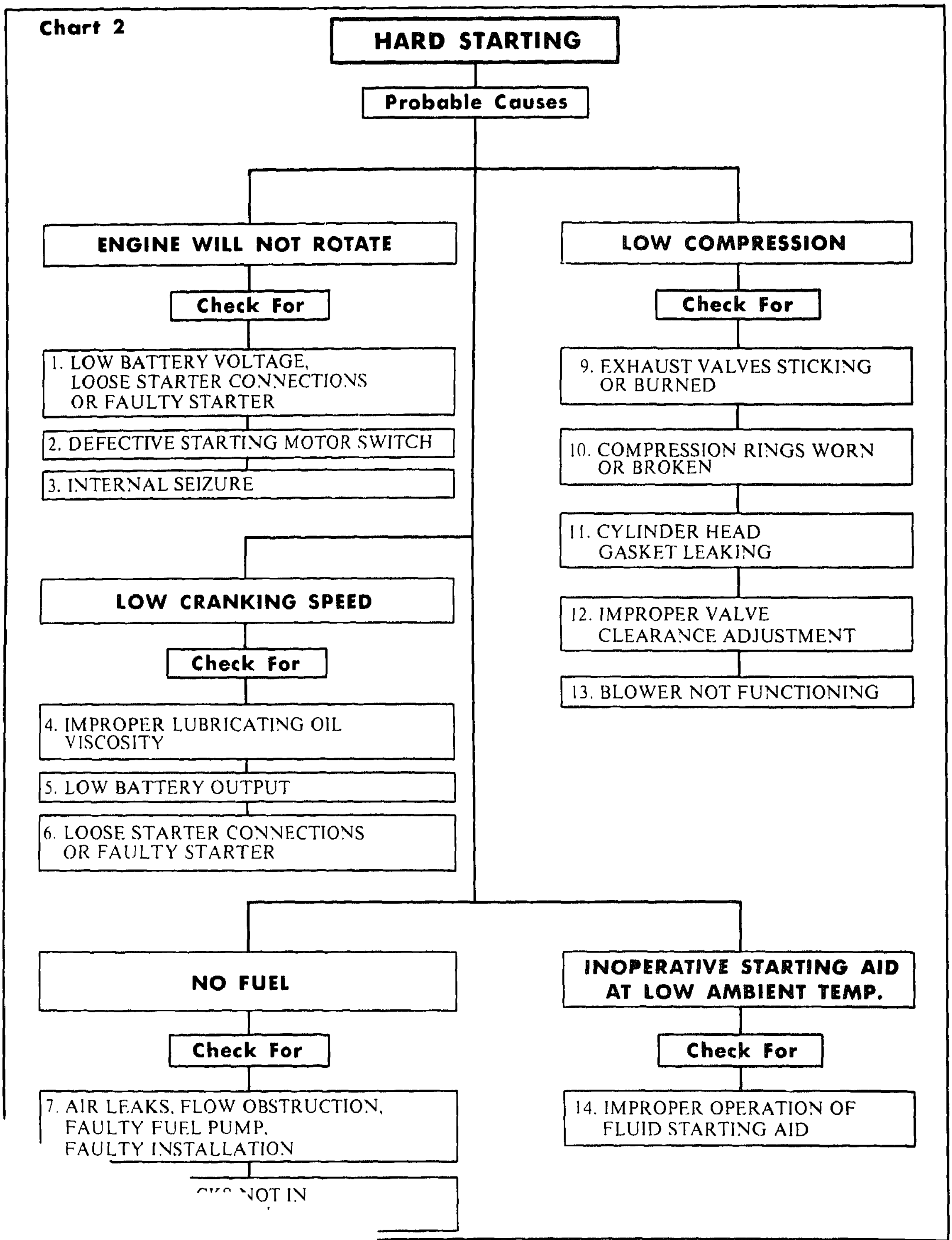


Chart 2
HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
NO FUEL
Check For
7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
NOT IN
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
14. IMPROPER OPERATION OF FLUID STARTING AID

Chart 2

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.

2. Replace the starting motor switch.

3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

4. Refer to *Lubricating Oil Specifications* in Section 13.3 for the recommended grade of oil.

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

Replace terminals that are damaged or corroded.

At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.

6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for bind in the governor-to-injector linkage. Readjust the governor and injector controls if necessary.

9. Remove the cylinder head and recondition the exhaust valves.

10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

12. Adjust the exhaust valve clearance.

13. Inspect the blower drive shaft and drive coupling. Replace damaged parts.

14. Operate the starting aid according to the instructions under *Cold Weather Starting Aids*.

Chart 3

ABNORMAL ENGINE OPERATION

Probable Causes

UNEVEN RUNNING OR FREQUENT STALLING

Check For

1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)

LACK OF POWER

Check For

6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION

DETONATION

Check For

13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

Chart 3

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and, if the temperature does not reach 160 ° to 185 °F. while the engine is operating, consult the *Abnormal Engine Coolant Temperature* chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the *Hard Starting* chart if compression pressures are low.

5. Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

6. Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

10. Refer to Item 13 on Chart 4.

11. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 10 °F. temperature rise above 90 °F. will occur. Relocate the engine air intake to provide a cooler source of air.

12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

13. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

14. Refer to Item 1 of this chart.

15. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

Chart 4

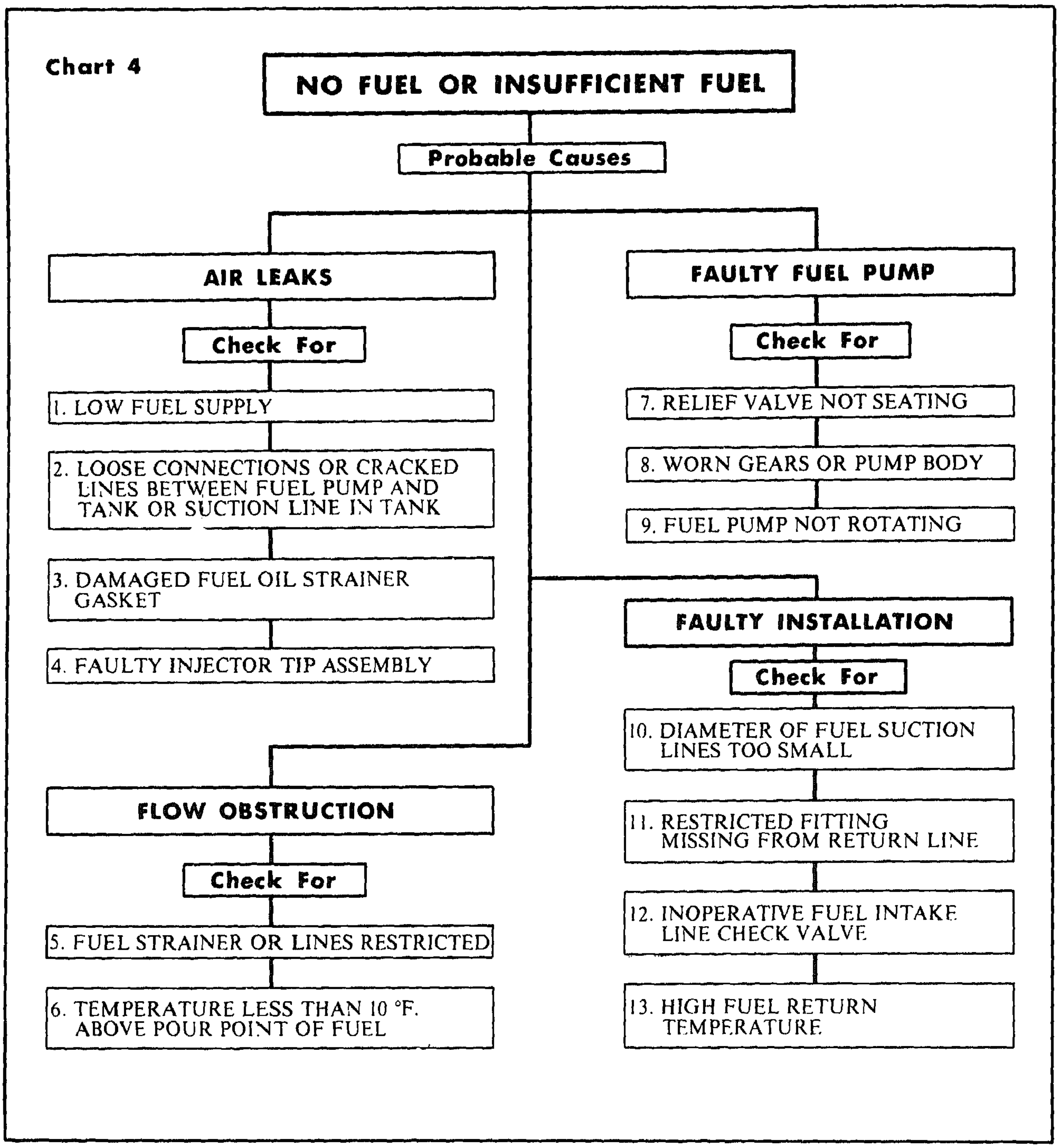

NO FUEL OR INSUFFICIENT FUEL
Probable Causes
AIR LEAKS
Check For
1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY
FAULTY FUEL PUMP
Check For
7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING
FAULTY INSTALLATION
Check For
10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE
FLOW OBSTRUCTION
Check For
5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10 °F. ABOVE POUR POINT OF FUEL

Chart 4

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.

2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.

3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element.

4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.

5. Perform a *Fuel Flow Test* and replace the fuel strainer and filter elements and the fuel lines, if necessary,

6. Consult the *Fuel Oil Specifications* for the recommended grade of fuel.

7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.

8. Replace the gear and shaft assembly or the pump body.

9. Check the condition of the fuel pump drive and blower drive and replace defective parts.

10. Replace with larger tank-to-engine fuel lines.

11. Install a restricted fitting in the return line.

12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.

13. Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150 °F. or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

Chart 5

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. HIGH CRANKCASE PRESSURE
4. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

5. BLOWER OIL SEAL LEAKING
6. OIL COOLER CORE LEAKING

OIL CONTROL AT CYLINDER

Check For

7. OIL CONTROL RINGS WORN, BROKEN OR IMPROPERLY INSTALLED
8. PISTON PIN RETAINER LOOSE
9. SCORED LINERS, PISTONS OR OIL RINGS
10. PISTON AND ROD ALIGNMENT
11. EXCESSIVE INSTALLATION ANGLE
12. EXCESSIVE OIL IN CRANKCASE

SUGGESTED REMEDY

1. Tighten connections or replace defective parts.

2. Replace defective gaskets or oil seals.

3. Refer to the *Excessive Crankcase Pressure* chart.

4. Refer to the *Abnormal Engine Operation* chart.

5. Remove the air inlet housing and inspect the blower end plates while the engine is operating. If oil is seen on the end plate radiating away from the oil seal, overhaul the blower.

6. Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.

7. Replace the oil control rings.

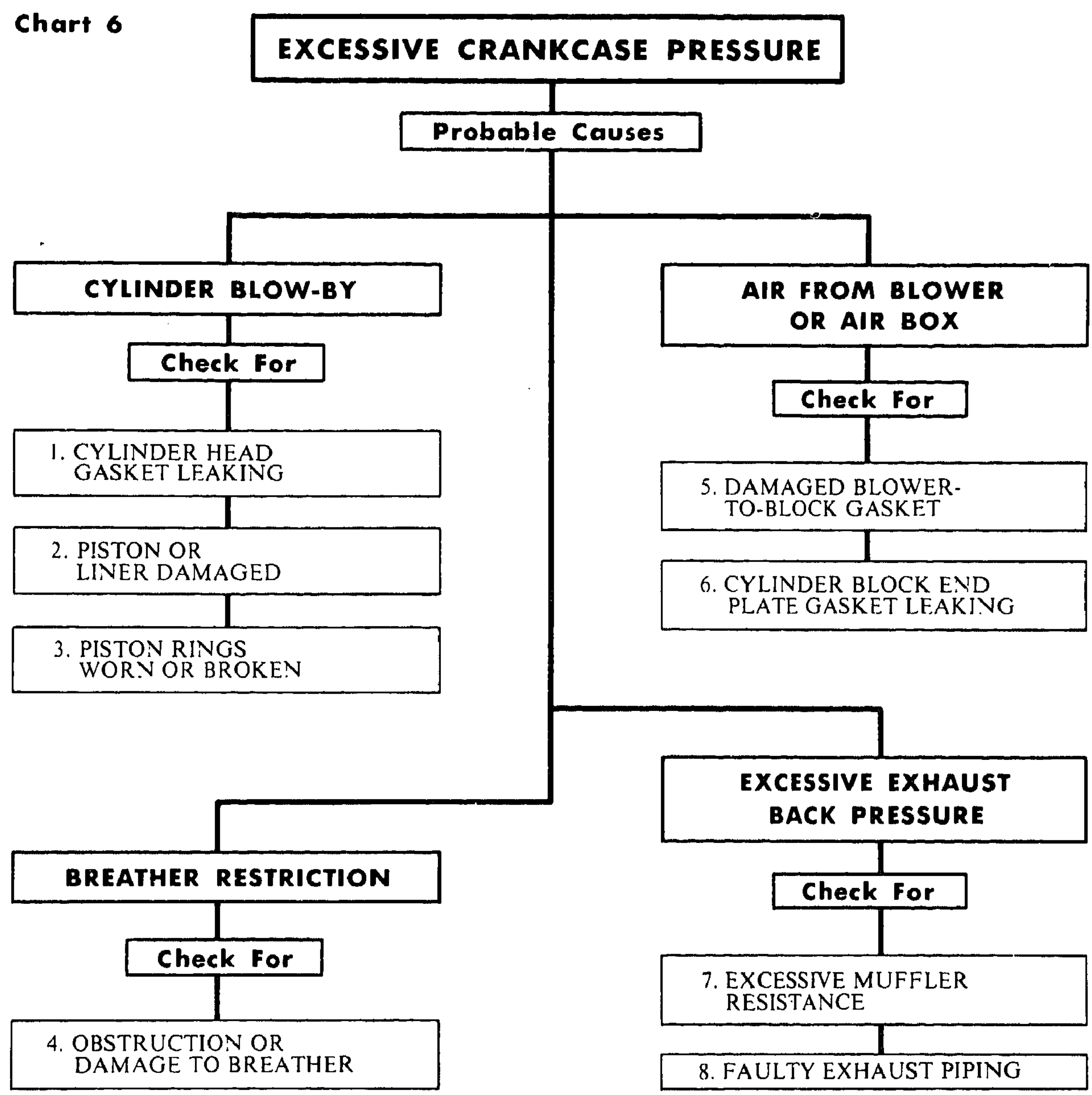
8. Replace the piston pin retainer and defective parts.

9. Remove and replace the defective parts.

10. Check the crankshaft thrust washers for wear. Replace worn and defective parts.

11. Decrease the installation angle.

12. Fill the crankcase to the proper level only.



SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.

2. Inspect the piston and liner and replace damaged parts.

3. Install new piston rings.

4. Clean and repair or replace the breather assembly.

5. Replace the blower-to-block gasket.

6. Replace the end plate gasket.

7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.

8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

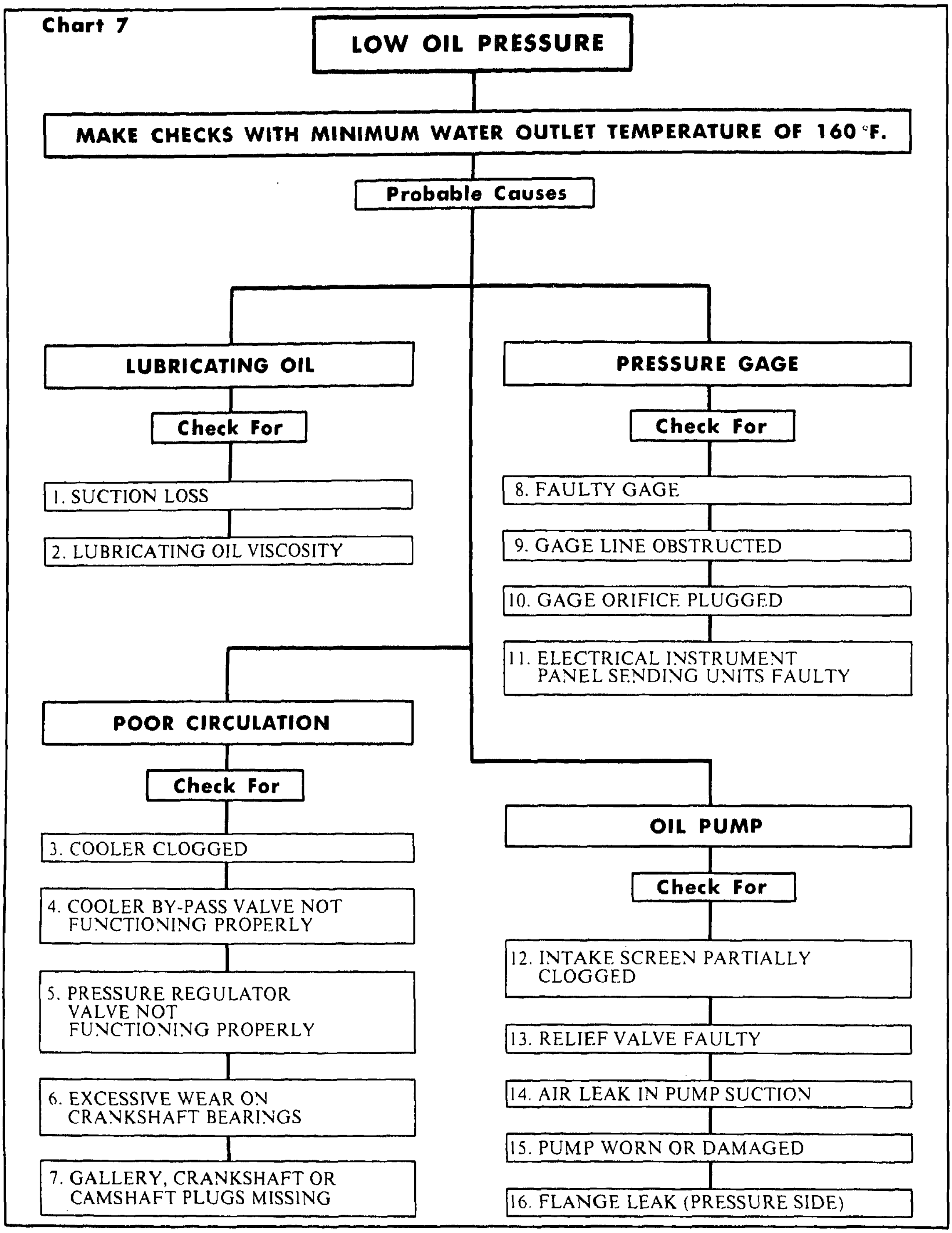


Chart 7
LOW OIL PRESSURE
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 °F.
Probable Causes
LUBRICATING OIL
Check For
1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY
PRESSURE GAGE
Check For
8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY
POOR CIRCULATION
Check For
3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING
OIL PUMP
Check For
12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

2. Consult the *Lubricating Oil Specifications* in Section 13.3 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution.

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the by-pass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubricating Oil Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

7. Replace missing plugs.

8. Check the oil pressure with a reliable gage and replace the gage if found faulty.

9. Remove and clean the gage line; replace it, if necessary.

10. Remove and clean the gage orifice.

11. Repair or replace defective electrical equipment.

12. Remove and clean the oil pan and oil intake screen. Consult the *Lubricating Oil Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the flange and replace the gasket.

Chart 8

ABNORMAL ENGINE COOLANT OPERATING TEMPERATURE

Probable Causes

ABOVE NORMAL

Check For

1. INSUFFICIENT HEAT TRANSFER
2. POOR CIRCULATION

BELOW NORMAL

Check For

3. IMPROPER CIRCULATION
4. EXCESSIVE LEAKAGE AT THERMOSTAT SEAL

SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 days or less)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.

2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.

3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

NOTE: Do not drain the fuel system or the crankcase after this run.

4. Check the air cleaner and service it, if necessary, as outlined in Section 3.1.

5. If freezing weather is expected during the storage period, add a high boiling point type antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the drain cocks open.

6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.

7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission, and priming the raw water pump, if used.

EXTENDED STORAGE (30 days or more)

When an engine is to be removed from operation for an extended period of time, prepare it as follows:

1. Drain and thoroughly flush the cooling system with clean, soft water.

2. Refill the cooling system with clean, soft water.

3. Add a rust inhibitor to the cooling system (refer to *Corrosion Inhibitors* in Section 13.3).

4. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.

5 Reinstall the injectors in the engine, time them, and adjust the exhaust valve clearance.

6. Circulate the coolant through the entire system by operating the engine until normal operating temperature is reached (160°F. to 185°F.).

7. Stop the engine.

8. Remove the drain plug and completely drain the engine crankcase. Reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.

9. Fill the crankcase to the proper level with a 30-weight preservative lubricating oil MIL-L-21260, Grade 2 (P10), or equivalent.

10. Drain the engine fuel tank.

11. Refill the fuel tank with enough rust preventive

fuel oil such as American Oil Diesel Run-In Fuel (LF-4089), Mobil 4Y17, or equivalent, to enable the engine to operate 10 minutes.

12. Drain the fuel filter and strainer. Remove the retaining bolts, shells and elements. Discard the used elements and gaskets. Wash the shells in clean fuel oil and insert new elements. Fill the cavity between the element and shell about two-thirds full of the same rust preventive compound as used in the fuel tank and reinstall the shell.

13. Operate the engine for 5 minutes to circulate the rust preventive throughout the engine.

14. Refer to Section 3.1 and service the air cleaner.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the valve rocker cover(s) and pour at least one-half gallon of oil, of the same grade as used in the crankcase, over the rocker arms and push rods.

2. Reinstall the valve rocker cover(s).

3. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*

4. Wash the exterior of the engine with fuel oil to remove the rust preventive.

5. Remove the rust preventive from the flywheel.

6. Remove the paper strips from between the pulleys and the belts.

7. Check the crankcase oil level. Fill the crankcase to the proper level with the heavy-duty lubricating oil recommended under *Lubricating Oil Specifications* (Section 13.3).

8. Fill the fuel tank with the fuel specified under *Diesel Fuel Oil Specifications* (Section 13.3).

9. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a high boiling point type antifreeze solution (refer to Section 13.3).

10. Install and connect the battery.

11. Service the air cleaner as outlined in Section 3.1.

ALPHABETICAL INDEX

*General Information Section

*General Information Section

*General Information Section

PART III

ENGINE PARTS MANUAL

STEEL WHEEL ROLLER C350B-D

CONTRACT NO. DSA 700-74-C-9024

oup No.	Description	Page No.

GENERAL INFORMATION

All engine components in this catalog are divided into seven major groups of functionally related parts.

Each Engine Model is provided with a Model Index, which shows the Standard and Standard Option type numbers currently available on the model. All optional material type numbers are listed on the engine Option Plate, as shown in the illustration below.

The names and type numbers of optional equipment built into the unit at the factory are listed on this plate, along with the unit model, serial number and customer specification number (if any). Material not listed on the Option Plate is standard equipment and the type number is obtained from the model index. (Copies of the information, on the Option Plate Work Sheet, are furnished to distributors for their files.)

To locate a part, first, establish the group where the part is used (see the Alphabetical Index or Group Nomenclature page), With this information, turn to the proper group.

Example:

For purposes of illustration, a Model 5033-7101, serial number 3D-1417 RC engine, will be used. To determine the proper part number of the fan pulley

As indicated in the Group Nomenclature page, the Fan is

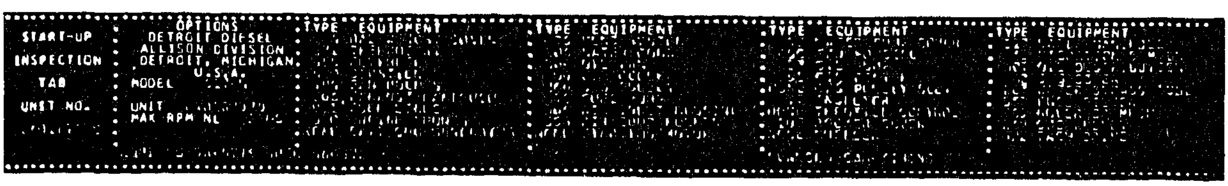
group 5.4235

The part is illustrated in Figure 4A, identified as being in group 5.4235.

To determine the proper part number of the cylinder block end plate, again refer to the Option Plate to note that there is no reference to the cylinder block – indicating that it is standard equipment.

To determine the proper fuel filter element part number, refer to the Option Plate to determine that the filter is standard equipment.

Turn to group 2.3000A and in the column note that the part number of the filter assembly, in sub-group 2.3310, is 5573949. However a note in the group heading refers to "Assembly Breakdown, Page B8 for components of the filter assembly. On page B8, the filter assembly 5573949 appears in column. All components of the filter assembly will be listed.



Delco-Remy electrical equipment is serviced by United Delco, Division of General Motors Corporation, from its outlets throughout the country. Part numbers of Delco-Remy items are listed for reference purposes only.

CAL INDEX:

betical Index is particularly en only a part name is known and the not readily be determined. Parts are abetically by noun name, followed by a of the application of the part and the p location. Component parts of assem- not listed since they will appear in the e book immediately following the assem- h they belong.

IEOUS:

inning of each of the 7 sections of this ere are several pages of illustrations. In on of the parts list figure numbers refer ations within that section only, unless noted. In the majority of cases illustra- typical, that is; they may represent more art number. For example, in the case of el housing, figure 5A of section 1.0000, a sing is shown to represent all housings. bers on illustrations are final group

nstances a part has more than one appli- herever a part appears in its second or cation the basic group is shown in paren- owing the description.

herwise specified, standard bolts in the are hexagon head. Other standard parts bed in detail.

The ASSEMBLY BREAKDOWN section is designed to eliminate repeating components of assemblies and sub-assemblies. When the Assembly Breakdown is used it is always follows the group it pertains to.

Assemblies which make use of the Assembly Breakdown will have a note to that effect under the sub-group heading. The note will refer to the page on which the assembly is shown. The part number will appear in the first group of the Assembly Breakdown showing the quantity used.

All other items appearing in that column are components of the assembly.

ALPHABETICAL INDEX

ALPHABETICAL INDEX

ALPHABETICAL INDEX

ALPHABETICAL INDEX

ALPHABETICAL INDEX

Part Name	Group No
H	
Head Assembly, Cylinder	1.2001
Head Assy., Cylinder	1.2001
Hose, Fuel Tank Flexible	2.6005
Hose, Oil Cooler Water Outlet Elbow	5.3422
Hose, Water By-Pass Tube	5.2165
Housing Assy., Air Inlet	3.3001
Housing, Air Inlet	3.3003
Housing, Blower	3.4020
Housing, Flywheel	1.5001
Housing, Gov. Control	2.7230
Housing, Governor Control	2.7230
Housing, Governor High Speed Spring Adjusting Screw	2.7635
Housing, Governor Limiting Speed Spring	2.7635
Housing, Governor Weight	2.7340
Housing, Oil Cooler	4.4050
Housing, Thermostat	5.2090
Hub, Idler Gear	1.7250
I	
Idler Pulley, Fan Belt	5.4235
Idler Pulley, Fan Belt (With Adjusting Arm)	5.4325
Impeller, Fresh Water Pump	5.1110
Injector Assy.	2.1001
Insert, Exhaust Valve	1.8330
L	
Lever Assy., Governor Control Operation Link	2.7317
Lever, Air Inlet Housing Shutdown Reset	3.3110
Lever, Air Inlet Housing Shutdown Valve	3.3090
Lever, Air Inlet Housing Shutdown Reset	3.3110
Lever, Air Inlet Housing Shutdown Valve	3.3090
Lever, Gov. Differential	2.7310
Lever, Gov. Operating Shaft	2.7280
Lever, Governor Cover Shutdown Shaft	2.7165
Lever, Governor Cover Shutdown Shaft	2.7165
Lever, Governor Cover Throttle Shaft	2.7170
Lever, Governor Cover Throttle Shaft	2.7170
Lever, Governor Differential	2.7310
Lever, Governor Operating	2.7280
Lever, Governor Operating Shaft	2.7280
Lever, Injector Control Tube	2.9009
Lever, Injector Control Tube Rack	2.9014
Liner, Cylinder	1.6180
Link, Governor Operating Lever Connecting	2.7312
Lock, Exhaust Valve Spring	1.8370

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T

ALPHABETICAL INDEX

INDEX

MODEL DESCRIPTION CHART
IN-LINE ENGINES

5 0 4 3 - 5 1 0 0

IES 3	NUMBER OF CYLINDERS	APPLICATION DESIGNATION (see below)	BASIC ENGINE ARRANGEMENTS *(see below)	DESIGN VARIATION (see below)	SPECIFIC MODEL NUMBER AND STARTER-BLOWER ARRANGEMENT

APPLICATION DESIGNATION

5042–5100	MARINE
5043–5100	FAN TO F/W—INDUSTRIAL
5044–5100	POWER-BASE
5045–5100	GENERATOR
5047–5100	FAN TO F/W—AUTOMOTIVE

DESIGN VARIATIONS

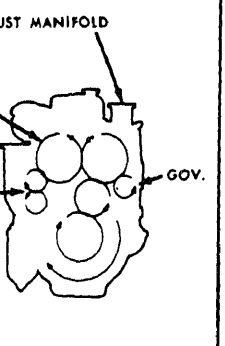
5043–5000	"N" ENGINE
5043–5100	2 VALVE HEAD
5043–5200	4 VALVE HEAD
5042–2302	TURBOCHARGER

STARTER-BLOWER ARRANGEMENT

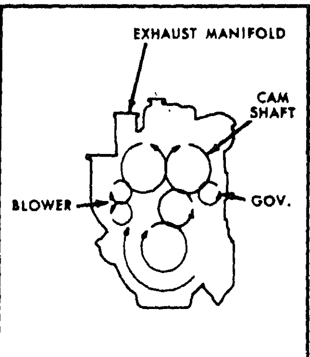
Odd number in last digit designates starter opposite blower.
Even number in last digit designates starter same side as blower.

*2, 3, 4-53 BASIC ENGINE ARRANGEMENTS

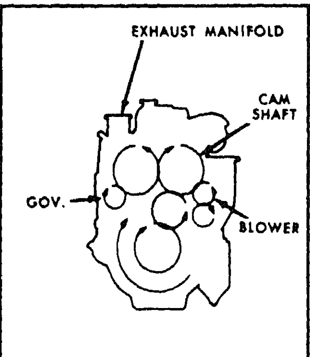
Rotation: L (left) and R (right) designates rotation viewed from the front of the engine.
Type: A-B-C-D designates location of exhaust manifold and blower as viewed from the rear (flywheel) end.



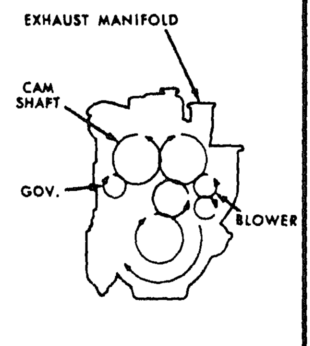
LA (XXXX-1XXX)



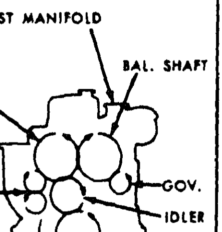
LB (XXXX-2XXX)

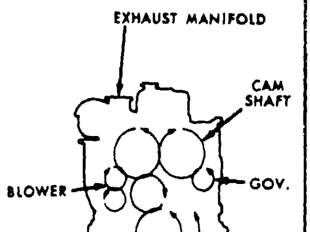


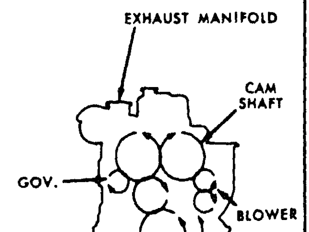
LC (XXXX-3XXX)

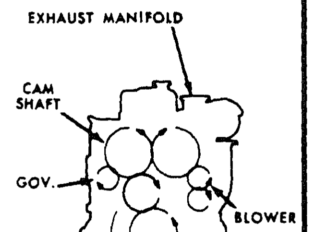


LD (XXXX-4XXX)









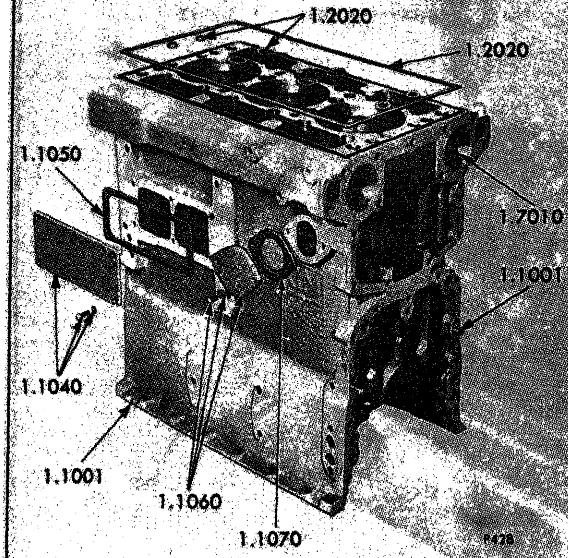


FIG. 1A INLINE 53
CYLINDER BLOCK
(with head gaskets)

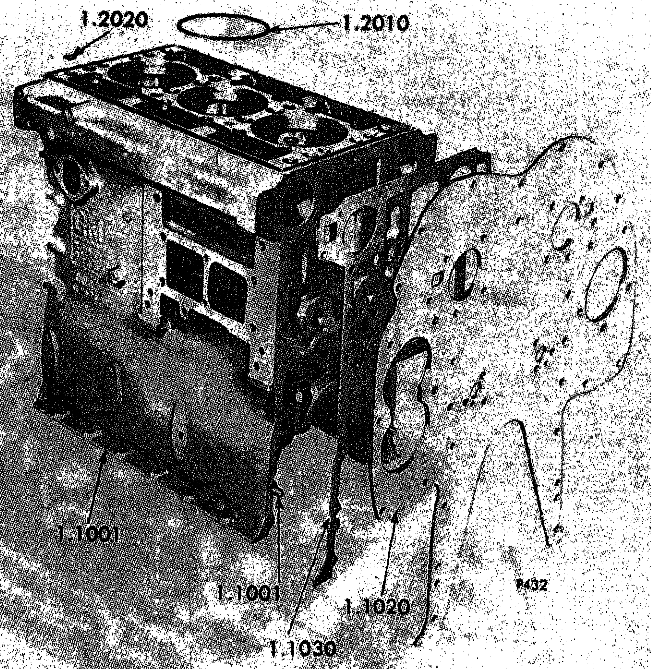


FIG. 1B INLINE 53
CYLINDER BLOCK
(with end plate)

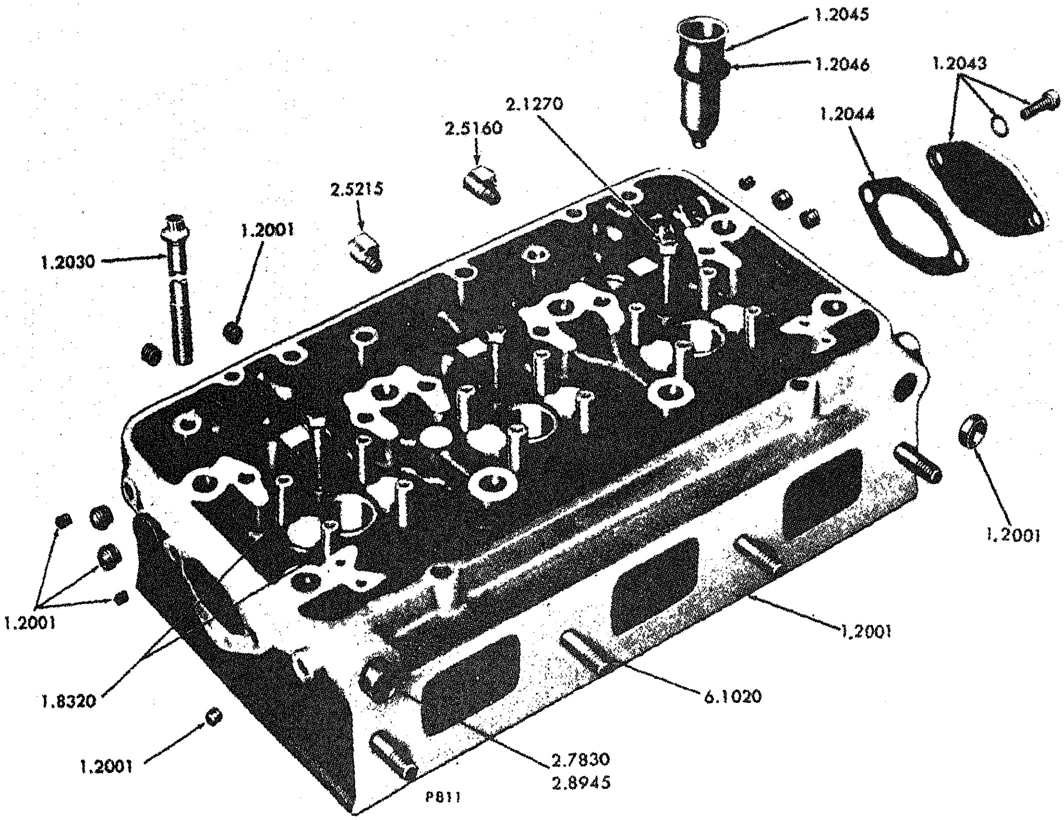
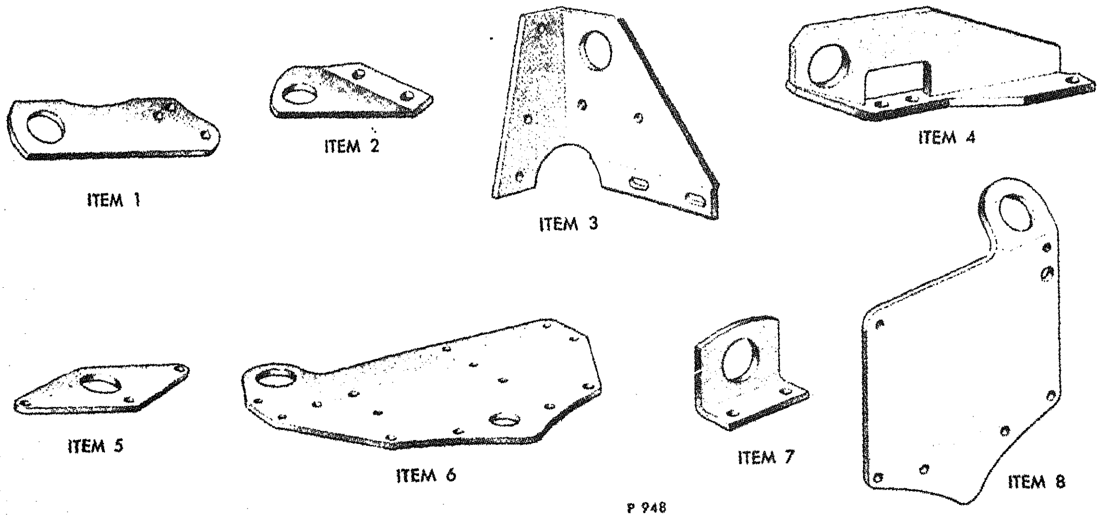


FIG. 2A CYLINDER HEAD



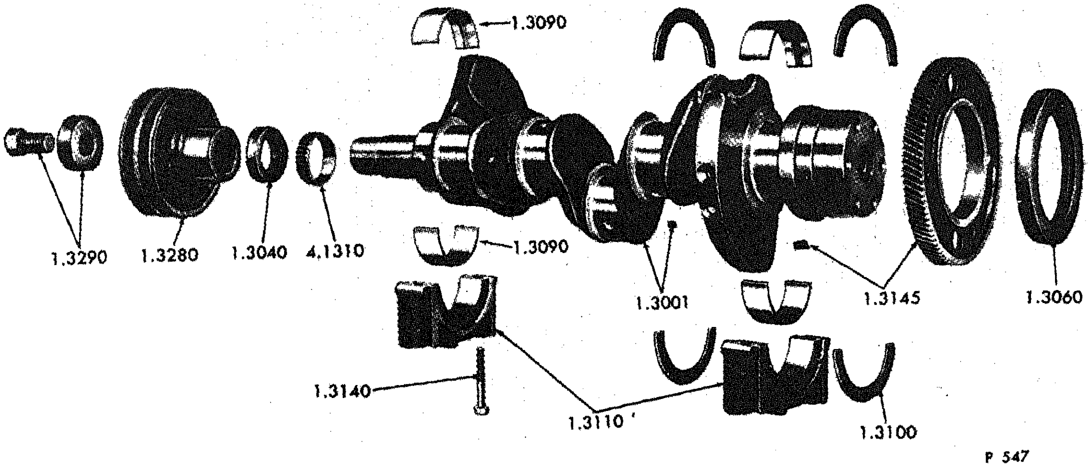


FIG. 3A CRANKSHAFT (3-53)

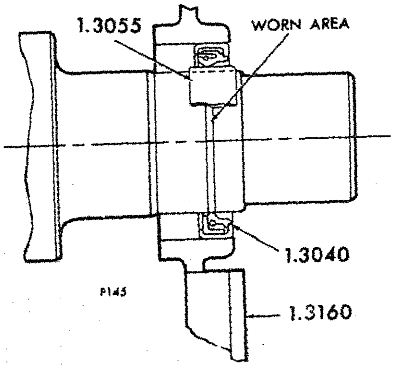
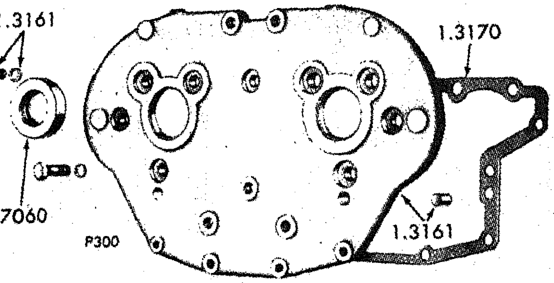


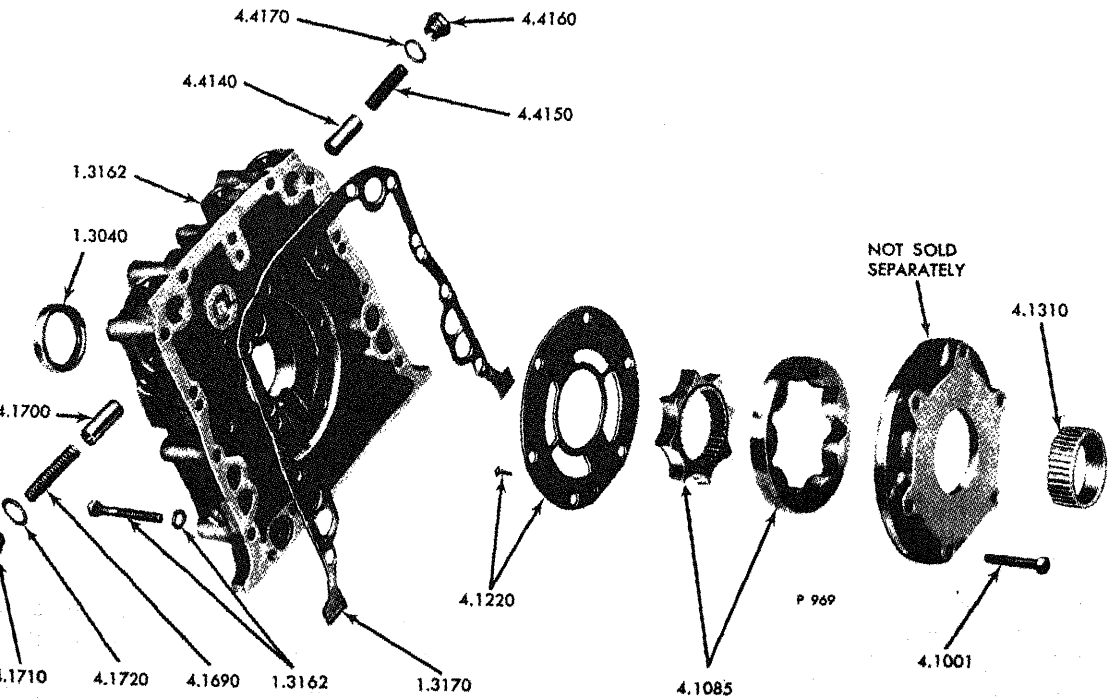
FIG. 3C CRANKSHAFT (3-53



In-Line Models

UPPER FRONT COVER

FIG. 4A



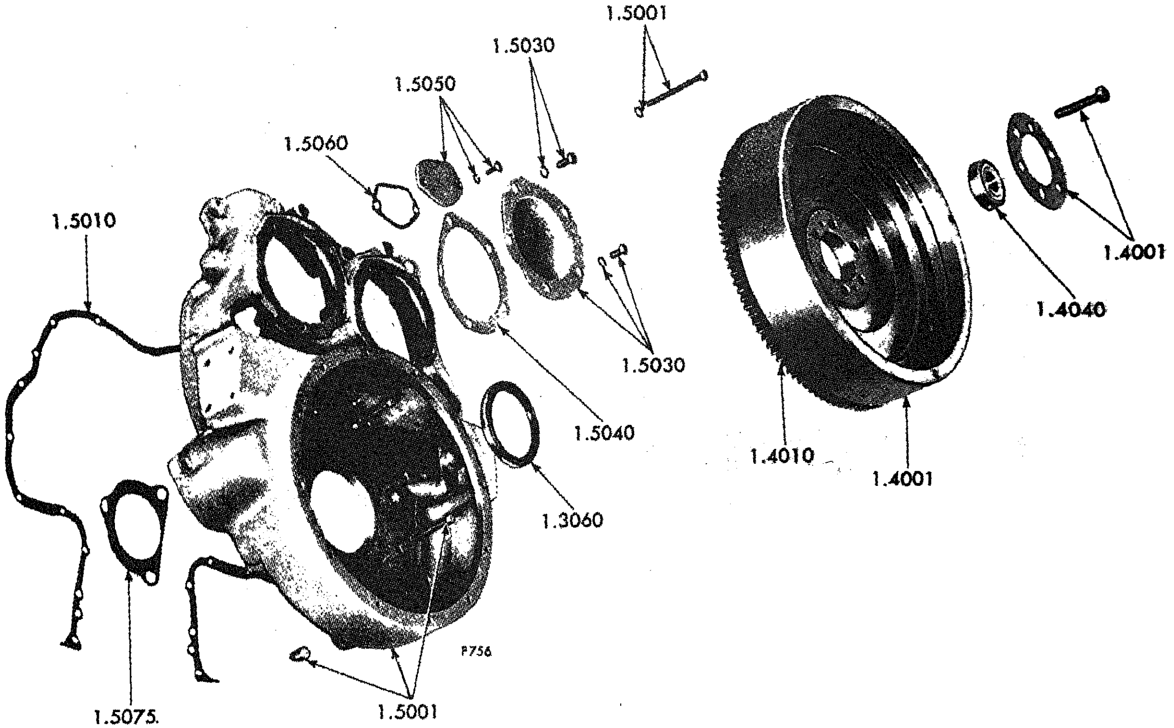


FIG. 5A FLYWHEEL AND FLYWHEEL HOUSING (In-Line Models)

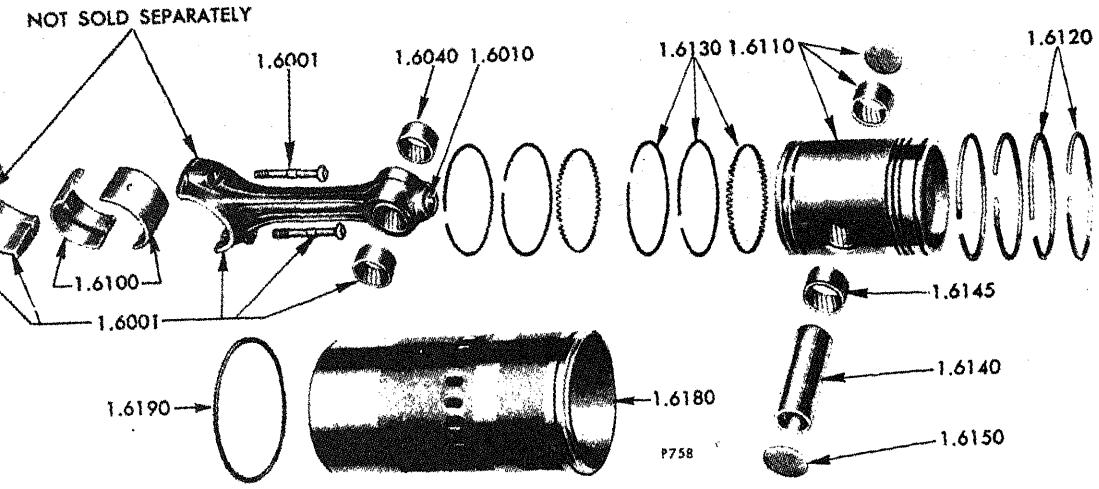


FIG. 6A CONNECTING ROD, PISTON AND LINER

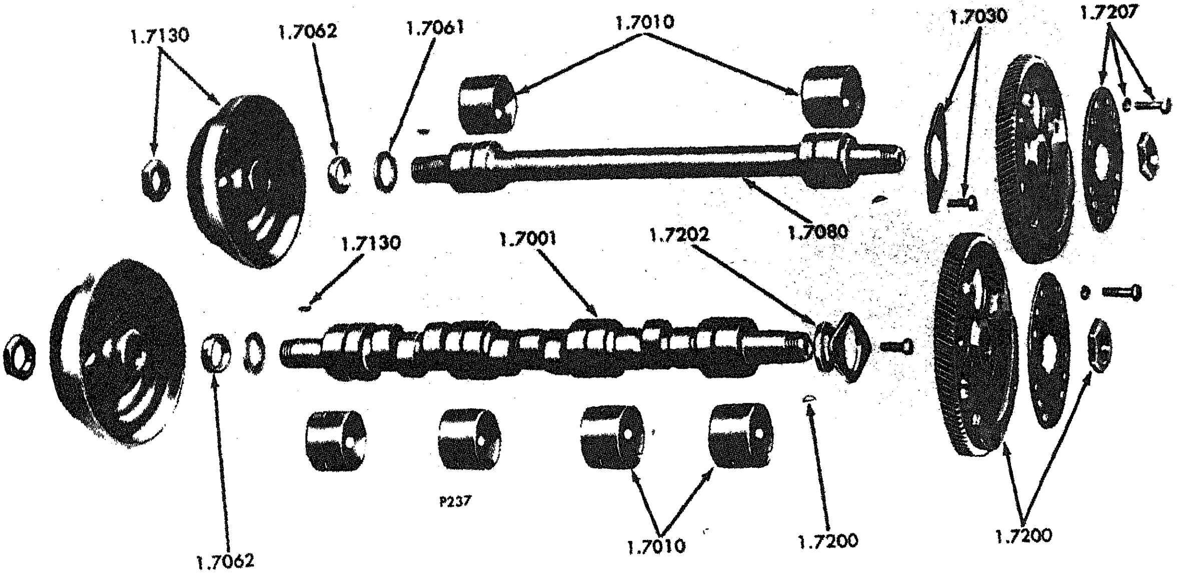


FIG. 7A CAMSHAFT (In-line Models)

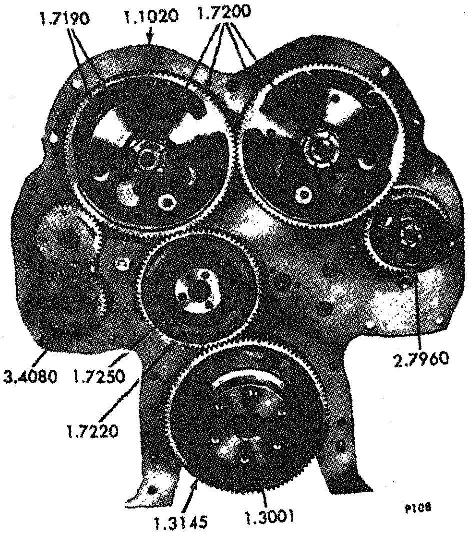


FIG. 7C GEAR TRAIN (Typical In-line)

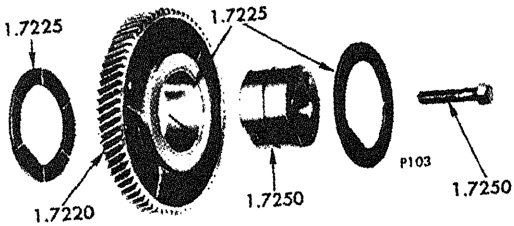


FIG. 7F IDLER GEAR

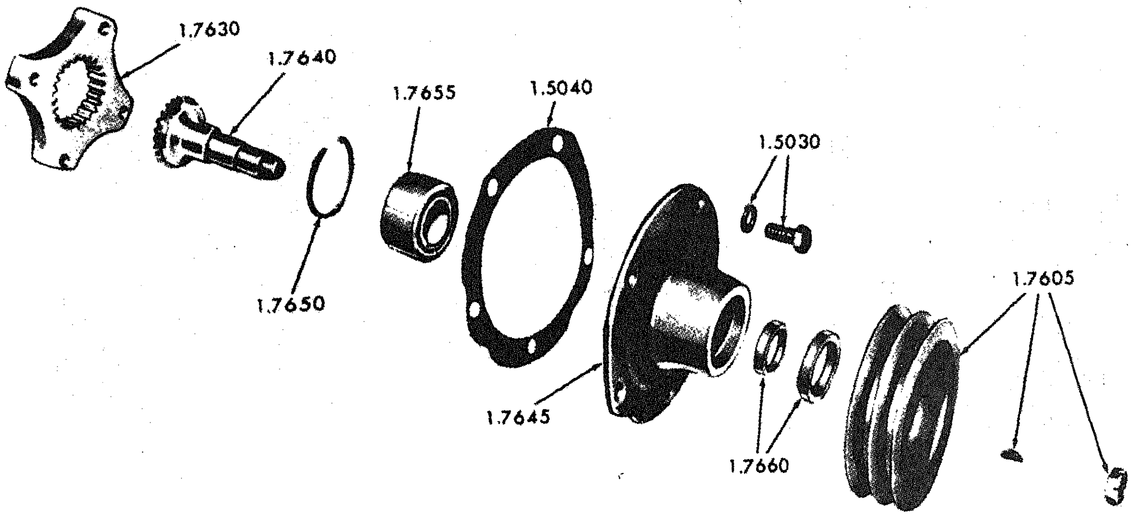


FIG. 8A ACCESSORY DRIVE (Double Belt)

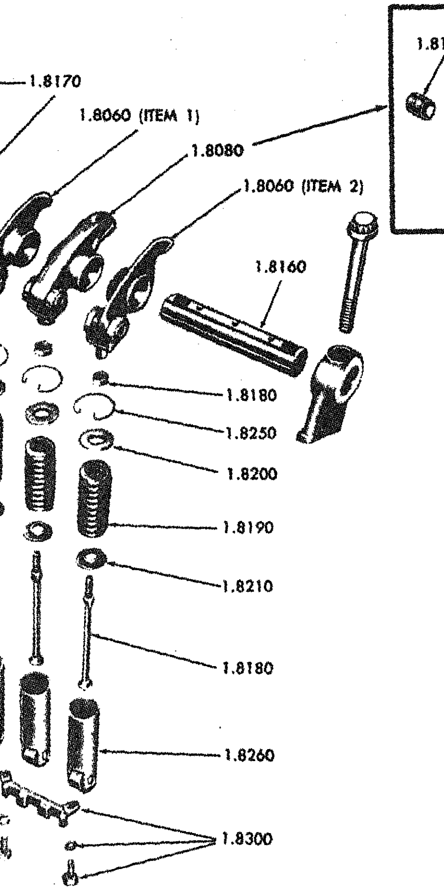


FIG. 9A
LVE MECHANISM

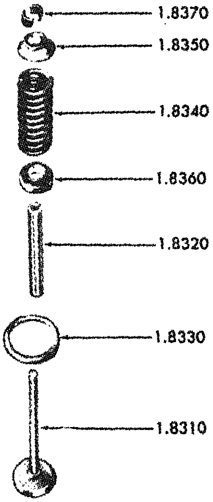


FIG. 9B
VALVE SPRING & SEAT

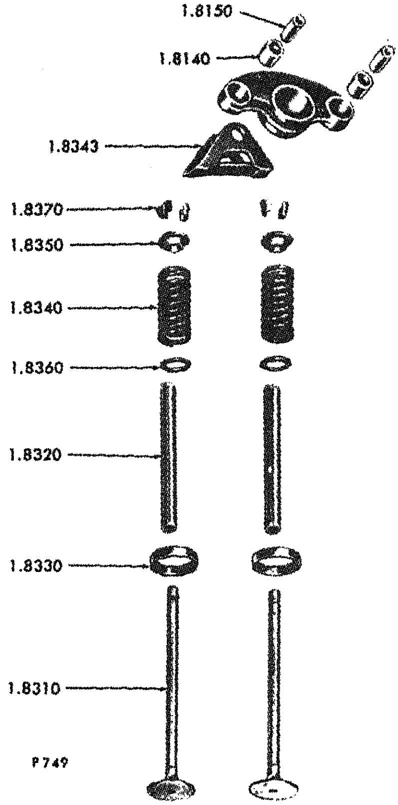
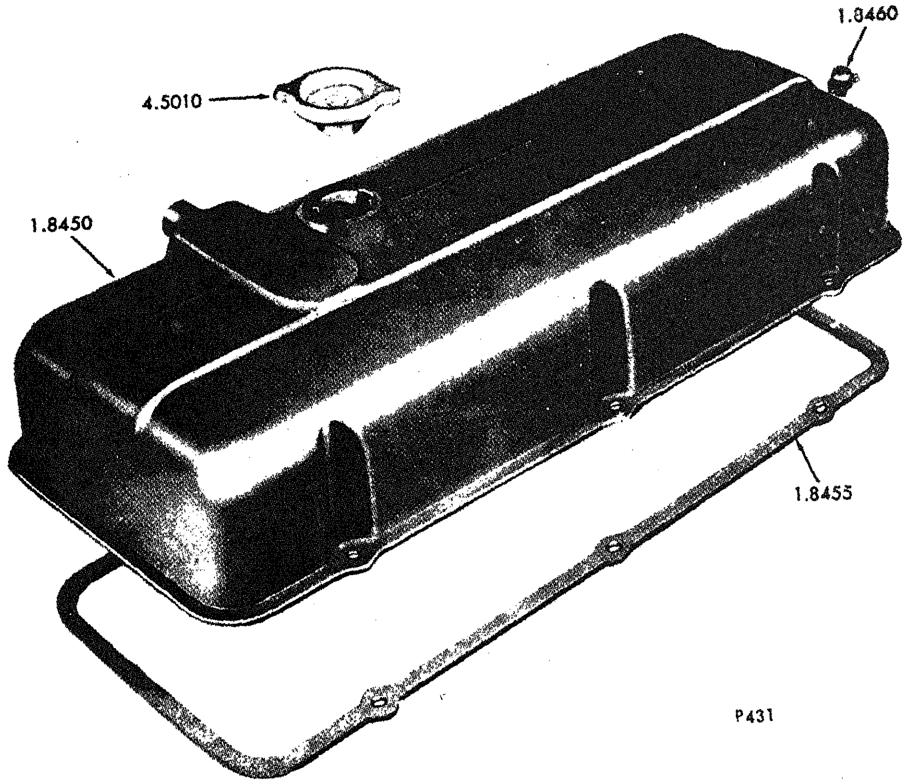
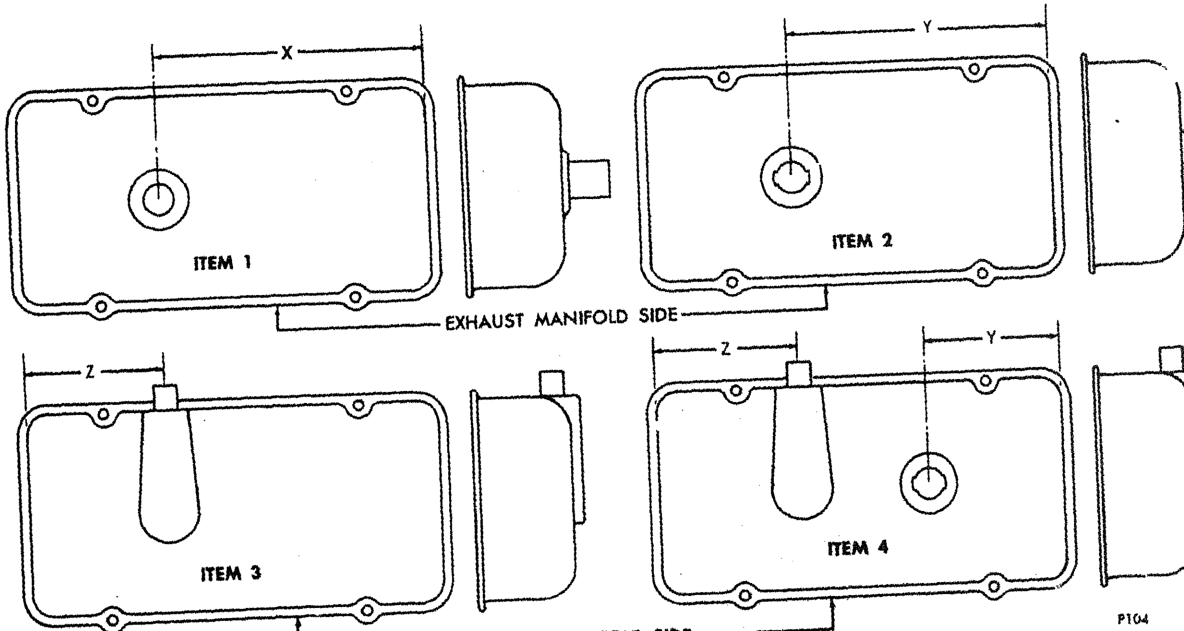
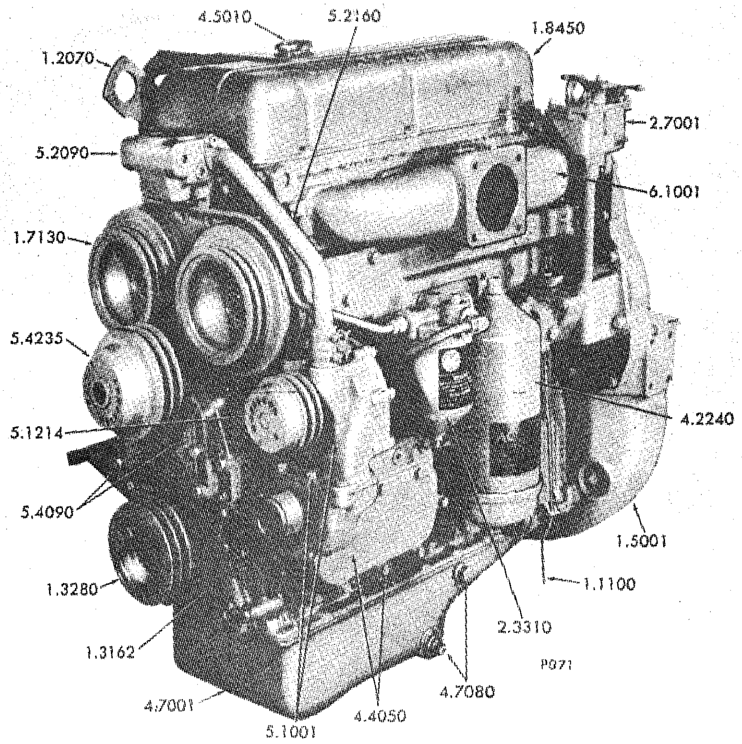


FIG. 9C
VALVE & ROCKER BRIDGE


1.8460
4.5010
1.8450
1.8455
P431


X
Y
ITEM 1
ITEM 2
EXHAUST MANIFOLD SIDE
Z
Z
Y
ITEM 3
ITEM 4
P104


4.5010
5.2160
1.8450
1.2070
2.7001
5.2090
6.1001
1.7130
5.4235
4.2240
5.1214
5.4090
1.5001
1.1100
1.3280
2.3310
1.3162
P071
4.7080
4.7001
4.4050
5.1001

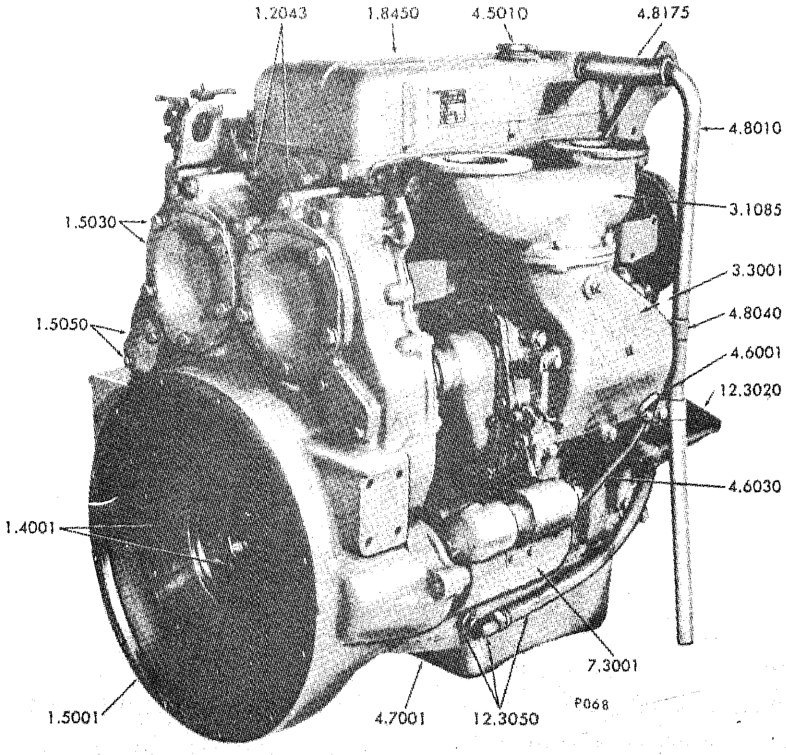

1.2043
1.8450
4.5010
4.8175
4.8010
3.1085
1.5030
3.3001
4.8040
1.5050
4.6001
12.3020
4.6030
1.4001
7.3001
P068
1.5001
4.7001
12.3050

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		1.1001 BLOCK ASSY., CYLINDER	
		FOR COMPONENTS OF SERVICE CYLINDER BLOCK ASSEMBLIES REFER TO ASSEMBLY BREAKDOWN PAGES AS INDICATED BELOW.	
1A,B	5196490	BLOCK ASSY. (PAGE A2)	1
		1.1002 GASKET KIT, ENGINE OVERHAUL	
		CONSISTS OF NECESSARY GASKETS FOR ONE ENGINE OVERHAUL	
	5199791	GASKET KIT	AR
		1.1020 PLATE, CYLINDER BLOCK END	
		A PLATE ASSY. INCLUDES PLUG NUTS.	
1B,7C	5121366	PLATE ASSY. (RC-RD-LC-LD ENG.)	1
	5121459	NUT, PLUG (3/8"-24)	8
	454813	BOLT, 3/8"-16X7/8" (12.9001)	13
	103321	LOCKWASHER, 3/8" (12.9200)	AR
		1.1030 GASKET, CYLINDER BLOCK END PLATE	
1B	5116354	GASKET	1
		1.1040 COVER, AIR BOX	
1A	5116373	COVER	1
1A	180120	BOLT, 3/8"-16X3/4" (12.9001)	6
1A	103321	LOCKWASHER, 3/8" (12.9200)	6
		1.1050 GASKET, AIR BOX COVER	
1A	5116380	GASKET	1
		1.1060 COVER, CYLINDER BLOCK WATER HOLE	
1A	5115097	COVER (3/8" TAPPED HOLE)	1
1A	186625	BOLT, 5/16"-18X7/8" (12.9001)	2
1A	103320	LOCKWASHER, 5/16" (12.9200)	2

IG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		<u>1.1070</u> GASKET, CYLINDER BLOCK WATER HOLE COVER	
A	5116357	GASKET	1
		A <u>1.1001</u> BLOCK CYLINDER	
	5196490	BLOCK ASSY. (3-53)	1
		THE FOLLOWING ITEMS ARE ASSEMBLED TO THE CYLINDER BLOCK:	
A	5116142	CAP, MAIN BEARING (UNFINISHED) (1.3110)	4
	5198209	BEARING SET, CAMSHAFT (1.7010)	1
	141346	PIN, 3/16"X1/2" DOWEL (12.9290)	4
	5116199	BOLT, MAIN BEARING CAP (1.3140)	8
		THE FOLLOWING ITEMS ARE "SHIPPED LOOSE" WITH THE CYLINDER BLOCK.	
	5146437	ELBOW, AIR BOX DRAIN TEE	1
	3231135	TEE, 1/4" INV. FL. (7.4586)	1
	141346	PIN, 3/16"X1/2" DOWEL (12.9290)	4
A,B	5146900	PIN, 3/8"X1 1/8" DOWEL (12.9290)	4
	114981	DRAINCOCK, 1/8" (12.9510)	1
	5145009	PLUG, 1/8" PIPE (12.9550)	7
	5145010	PLUG, 1/4" PIPE (12.9550)	1
	5150131	PLUG, 7/16" CUT (OIL HOLES)	2
	5121316	PLUG, 5/8"X13/32"	2
		<u>1.1100</u> TUBE, AIR BOX DRAIN	
G	5132286	TUBE (DEV. L. 12.00")	1
	137421	ELBOW, 1/4" INV. FL. TUBE 90DEG. (12.9480)	1
	137397	NUT, 1/4" INV. FL. TUBE (12.9500)	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUAN
		1.2001 HEAD ASSY. CYLINDER	
		FOR COMPONENTS OF SERVICE CYLINDER HEAD ASSEMBLIES REFER TO ASSEMBLY BREAKDOWN PAGE A5	
2A	5198203	HEAD ASSY. (4 VALVE) (3-53)	
	5144425	ADAPTOR, FUSE PLUG	
	5198655	PLUG, FUSE PLUG	
2A	5145009	PLUG, 1/8" PIPE (12.9550)	
2A	5121182	PLUG, 1/4" HEX. SKT. PIPE (2.4015)	
2A	5154453	PLUG, 3/8"-16 SL. HDLS.	
2A	5151449	PLUG, 13/16" CUP (1.1001)	
	5139997	PLUG, 7/8" DIA. CUP (STAINLESS)	
		1.2002 GASKET KIT, CYLINDER HEAD OVERHAUL	
		CONSISTS OF ALL GASKETS NECESSARY TO REPLACE ONE CYLINDER HEAD.	
	5199811	GASKET KIT, CYLINDER HEAD	A
		1.2005 NOZZLE, CYLINDER HEAD WATER	
	5119293	NOZZLE	
		1.2010 GASKET, CYLINDER HEAD COMPRESSION	
1B	5121254	GASKET	
		1.2020 GASKET SET, CYLINDER HEAD OIL	
1A	5116290	RING, SEAL (END WATER HOLE)	
1A	5121207	RING, SEAL (CENTER WATER HOLE)	
1B	5116122	RING, SEAL (OIL HOLE)	
1A	5116292	RING, SEAL	
		1.2030 BOLT, CYLINDER HEAD	
2A	5121263	BOLT, 5/8"-11X6 1/4" (12 PT. HD.)	
		1.2043 COVER, CYLINDER HEAD WATER HOLE	
10G	5123352	COVER (3/8" PIPE TAP)	
10G	5145010	PLUG, 1/4" PIPE HEX. SOC. HD. (12.9550)	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	1.2043 COVER, CYLINDER HEAD WATER HOLE (CONT.)	
5145011	PLUG, 3/8" PIPE SQ. HD. (12.9550)	2
5145012	PLUG, 1/2" PIPE SQ. HD. (12.9550)	1
179839	BOLT, 3/8"-16X1" (12.9001)	2
103321	LOCKWASHER, 3/8" (12.9200)	2
	1.2044 GASKET, CYLINDER HEAD WATER HOLE COVER	
5116242	GASKET	1
	1.2045 TUBE, INJECTOR HOLE	
5199527	TUBE KIT (INCLUDES SEAL RING IN 1.2046) (2.1290)	3
	1.2046 RING, INJECTOR HOLE TUBE SEAL	
5160037	RING (PART OF KIT IN 1.2045) (2.1300)	3

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		B 1.2001 HEAD ASSEMBLY, CYLINDER	
	5198203	HEAD ASSY. (4 VALVE)	1
		THE FOLLOWING ITEMS ARE ASSEMBLED TO THE CYLINDER HEAD.	
	5198655	PLUG, FUSE	1
	5154453	PLUG, 3/8"-16 SPECIAL	4
	5145009	PLUG, 1/8" PIPE (12.9550)	2
	5199527	TUBE KIT (INCLUDES RING 5160037) (1.2045)	3
	5160037	RING (2.2046)	3
	5116361	INSERT, EXHAUST VALVE (1.8330)	12
	5131961	GUIDE, EXHAUST VALVE (1.8320)	12
	5119293	NOZZLE, WATER (DOUBLE OUTLET) (1.2005)	4
		THE FOLLOWING ITEMS ARE "SHIPPED LOOSE" WITH THE CYLINDER HEAD.	
	5121182	PLUG, 1/4" PIPE (2.4015)	6
	5151449	PLUG, 13/16" CUP SPECIAL	3
	5116262	ADAPTOR, CYLINDER HEAD GOVERNOR CONTROL LINK (2.7830)	1
	5121252	ADAPTOR, CYLINDER HEAD GOVERNOR CONTROL LINK (2.7830)	1
	5111467	SEAT, EXHAUST VALVE SPRING (1.8360)	12
		1.2070 BRACKET, ENGINE LIFTER FRONT	
	5129750	BRACKET	1
	5164294	SPACER, 1/8" THICK (7.1581)	2
	9409028	BOLT, 3/8"-16X1" AA LOCK (12.9001)	2
		1.2080 BRACKET, ENGINE LIFTER REAR	
2B	5119379	BRACKET (ITEM 7)	1
	9409028	BOLT, 3/8"-16X1" (12.9001)	2

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	1.3001 CRANKSHAFT ASSY.	
	A CRANKSHAFT ASSY. INCLUDES PLUG AND DOWELL IN 1.3001. WHEN REPLACING A CRANKSHAFT ASSY. INCLUDE AN OIL PUMP DRIVE GEAR IN 4.1310	
5116447	CRANKSHAFT ASSY.	1
5198502	SLEEVE, CRANKSHAFT FRONT OIL SEAL (1.3056) (Use with 5198503 SEAL)	1
444687	PLUG, 1/8" PIPE (12.9550)	3
	1.3040 SEAL, CRANKSHAFT OIL - FRONT	
5198503	SEAL (SINGLE LIP O.S., USE WITH 5198502 SLEEVE)	1
5116224	SEAL	1
5148314	SEAL (W/EXCLUDER LIP)	1
	1.3055 SPACER, CRANKSHAFT FRONT OIL SEAL	
5198502	SLEEVE (USE WITH 5198503 SEAL) (1.3056)	1
	1.3060 SEAL, CRANKSHAFT OIL - REAR	
5116229	SEAL (SINGLE LIP, STANDARD)	1
5196852	SEAL (SINGLE LIP, O.S., USE WITH 5196851 SLEEVE)	AR
5199477	SEAL (DOUBLE LIP, O.S., USE WITH 5196851 SLEEVE)	AR
	1.3066 SLEEVE, CRANKSHAFT REAR OIL SEAL	
5196851	SLEEVE (WITH O.S. OIL SEAL)	AR
	1.3090 SHELL, CRANKSHAFT MAIN BEARING	
	A SHELL SET CONSISTS OF ONE UPPER AND ONE LOWER SHELL.	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	1.3090 SHELL, CRANKSHAFT MAIN BEARING (CONT'D)	
5196647	SHELL, LOWER (.010" U.S.)	AR
5196648	SHELL, UPPER (.020" U.S.)	AR
5196649	SHELL, LOWER (.020" U.S.)	AR
5196650	SHELL, UPPER (.030" U.S.)	AR
5196651	SHELL, LOWER (.030" U.S.)	AR
5195928	SHELL SET (STANDARD) (1 HOLE)	AR
5196660	SHELL SET (.002" U.S.)	AR
5196661	SHELL SET (.010" U.S.)	AR
5196662	SHELL SET (.020" U.S.)	AR
5196663	SHELL SET (.030" U.S.)	AR
	1.3100 WASHER, CRANKSHAFT MAIN BEARING THRUST	
5116197	WASHER (STANDARD)	4
5196755	WASHER (.005" O.S.)	AR
5196756	WASHER (.010" O.S.)	AR
141346	PIN, 3/16"X1/2" DOWEL (12.9290)	4
5149149	PIN, 7/32"X1/2" DOWEL (1/32" O.S.)	AR
	1.3110 CAP, CRANKSHAFT MAIN BEARING	
5195935	CAP	4
5116142	CAP (UNFINISHED)	AR
	1.3140 BOLT, CRANKSHAFT MAIN BEARING CAP	
5116199	BOLT	8
	1.3145 GEAR, CRANKSHAFT TIMING	
5116195	GEAR	1
127559	KEY, 1/4"X3/4" WOODRUFF (12.9350)	1
	1.3161 COVER, ENGINE FRONT-UPPER	
	AN UPPER COVER ASSY. INCLUDES PINS AND PLUGS IN 1.3161.	
5101347	COVER ASSY.	1
5146900	PIN, 3/8"X1 1/8" DOWEL (12.9290)	2

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	1.3162 COVER, ENGINE FRONT-LOWER	
	A LOWER COVER ASSY. INCLUDES ITEMS IN 4.1690 THRU 4.7120	
5197415	COVER ASSY.	1
5145009	PLUG, 1/8" PIPE HEX SOC. HD. (12.9550)	1
186282	BOLT, 3/8"-16X3 1/4" (12.9001)	7
103321	LOCKWASHER, 3/8" (12.9200)	7
5146648	PLUG, 1/2" - 14 HEX SOCKET	7
	1.3170 GASKET, ENGINE FRONT COVER	
5121082	GASKET (UPPER)	1
5116386	GASKET (LOWER)	1
	1.3280 PULLEY, CRANKSHAFT	
5116484	PULLEY (5.38" DIA., 2 GROOVES)	1
	1.3290 RETAINER, CRANKSHAFT PULLEY	
5180291	RETAINER (WASHER)	1
5180629	% BOLT, 3/8"-16X1 3/4" L.	1
271632	BOLT, 3/4"-16X1 3/4" (12.9001)	1
	% OPTIONAL HAS COUNTERBORE FOR HAND TACHOMETER	
	1.3320 BELT, CRANKSHAFT PULLEY	
	SIZES GIVEN ARE EFFECTIVE LENGTH AT WIDTH SHOWN. ALL BELTS ARE "PREMIUM" POLYESTER BELTS, UNLESS INDICATED (M.S.) "MILITARY STANDARD".	
5126447	BETL SET (2 BELTS) (35.00" L., .500" W.)	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANT
		1.4001 FLYWHEEL	
		INCLUDES GEAR IN 1.4010. "C" INDICATES A CHAMFERED ASSY. "NC" IS NON-CHAMFERED.	
5A	5126671	PLATE, SCUFF (BOLT RETAINER)	1
5A	9412018	BOLT, LOCK (2 1/4" L.)	6
5A	5126587	FLYWHEEL ASSY. (SAE #3) (NC)	1
		1.4010 GEAR, FLYWHEEL RING	
5A	5116301	GEAR (SAE #3-126 TEETH)	1

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	<u>1.5001</u> HOUSING, FLYWHEEL	
5146903	HOUSING (SAE #3)	1
5145011	PLUG, 3/8" PIPE (12.9550)	1
5145013	PLUG, 3/4" PIPE (12.9550)	1
5146646	PLUG, 1 1/4" PIPE (12.9550)	1
427588	BOLT, 3/8"-16X2 1/2" (12.9001)	6
179838	BOLT, 3/8"-16X7/8" (12.9001)	5
9409126	BOLT, 5/16"-18X2 1/2" (12.9001)	2
9414215	BOLT, 3/8"-16X 2 1/2" (12.9001)	4
5170489	BOLT, 3/8"-24X3 9/16" (12.9001)	3
9409079	BOLT, 3/8"-16X7/8" (12.9001)	1
9409079	BOLT, 3/8"-16X7/8" (12.9001)	1
103321	LOCKWASHER, 3/8" (12.9200)	AR
	<u>1.5002</u> SHIM, FLYWHEEL	
5123802	SHIM	1
	<u>1.5010</u> GASKET, FLYWHEEL HOUSING	
5121334	GASKET	1
	<u>1.5020</u> GASKET, FLYWHEEL HOUSING BELL	
5127184	GASKET	1
	<u>1.5030</u> COVER, FLYWHEEL HOUSING LARGE HOLE	
5122281	COVER	1
179857	BOLT, 7/16"-14X1" (12.9001)	2
100158	BOLT, 1/2"-13X1" (12.9001)	8
5150568	WASHER, 7/16" UPPER (2.4050)	2
103323	LOCKWASHER, 1/2" (12.9200)	8
	<u>1.5040</u> GASKET, FLYWHEEL HOUSING LARGE HOLE COVER	
5117061	GASKET	2
	<u>1.5050</u> COVER, FLYWHEEL HOUSING SMALL HOLE	
5116411	COVER	1
186625	BOLT, 5/16"-18X7/8" (12.9001)	2
103320	LOCKWASHER, 5/16" (12.9200)	[illegible]

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUAN
		1.6001 CONNECTING ROD ASSY.	
		QUANTITIES SHOWN ARE PER CYLINDER. A ROD ASSY. INCLUDES CAP AND ORIFICE WHICH ARE NOT SOLD SEPARATELY, PLUS ITEMS IN 1.6001, 1.6010 AND 1.6040.	
6A	5121262	ROD ASSY.	1
6A	5197852	BOLT (3/8"-24X2.76" L.)	2
6A	839103	NUT (3/8"-24 HEX.)	2
		1.6010 NOZZLE, CONNECTING ROD SPRAY	
6A	5150140	NOZZLE	2
		1.6040 BUSHING, CONNECTING ROD PISTON PIN	
6A	5116181	BUSHING	2
		1.6100 SHELL, CONNECTING ROD BEARING	
		A SHELL SET CONSISTS OF ONE UPPER AND ONE LOWER SHELL.	
6A	5121247	SHELL, UPPER (STD.)	1
6A	5116187	SHELL, LOWER (STD.)	1
6A	5196652	SHELL, UPPER (.002" U.S.)	AR
6A	5196653	SHELL, LOWER (.002" U.S.)	AR
6A	5196654	SHELL, UPPER (.010" U.S.)	AR
6A	5196655	SHELL, LOWER (.010" U.S.)	AR
6A	5196656	SHELL, UPPER (.020" U.S.)	AR
6A	5196657	SHELL, LOWER (.020" U.S.)	AR
6A	5196658	SHELL, UPPER (.030" U.S.)	AR
6A	5196659	SHELL, LOWER (.030" U.S.)	AR
	5195929	SHELL SET (STANDARD)	AR
	5196664	SHELL SET (.002" U.S.)	AR
	5196665	SHELL SET (.010" U.S.)	AR
	5196666	SHELL SET (.020" U.S.)	AR
	5196667	SHELL SET (.030" U.S.)	AR

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	1.6110 PISTON ASSY.	
	A PISTON ASSY. INCLUDES BUSHING IN 1.6145 AND RETAINER IN 1.6150. VAPOR BLASTED BUSHINGS (TYPES 58, 59,94) NOT SERVICED SEPARATELY.	
5198877	PISTON ASSY. ("N" ENGINE")	1
	1.6115 RING SET, PISTON	
	A PISTON RING SET CONSISTS OF SUFFICIENT RINGS FOR ONE (1) CYLINDER.	
5198822	RING SET	AR
	1.6120 RING, PISTON COMPRESSION	
5140340	RING (FIRE RING)	1
5116184	RING (CHROMED) (2ND, 3RD, AND 4TH) TWO COMPRESSION GROOVES ONLY.	3
	1.6130 RING, PISTON OIL CONTROL	
	AN OIL CONTROL RING SET CONSISTS OF RINGS FOR ONE (1) CYLINDER. AN OIL CONTROL RING CONSISTS OF TWO (2) SCRAPERS AND ONE (1) EXPANDER.	
5195933	RING	2
	1.6140 PIN, PISTON	
5116189	PIN	1
	1.6145 BUSHING, PISTON PIN	
5116181	BUSHING (1.6040)	2
	1.6150 RETAINER, PISTON PIN	
5180250	RETAINER	2

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QU
		1.6182 CYLINDER KIT	
		A CYLINDER KIT CONSISTS OF ITEMS IN 1.6110, 1.6115, 1.6120, 1.6140, 1.6180 AND 1.6190 FOR ONE CYLINDER.	
	5198899	CYLINDER KIT ("N" ENGINES)	
		1.6190 SEAL, CYLINDER LINER	
6A	5121256	SEAL	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	1.7001 CAMSHAFT ASSY.	
	A CAMSHAFT ASSY. INCLUDES PLUG IN 1.7001	
5126929	CAMSHAFT ASSY. (RB-RC-LA-LD ENG.)	1
5151277	PLUG (1/2" DRIVE)	2
	1.7010 BEARING, CAM AND BALANCER SHAFT	
	A SET INCLUDES ALL END AND INTERMEDIATE BEARINGS WHICH ARE NOT SOLD SEPARATELY.	
5198209	BEARING SET (STD. I.D., STD. O.D.)	1
5198980	BEARING SET (STD. I.D., .010" O.S., O.D.)	AR
5198470	BEARING SET (.010" U.S., I.D., STD. O.D.)	AR
5198471	BEARING SET (.020" U.S., I.D., STD. O.D.)	AR
	1.7030 WASHER, CAM AND BALANCER SHAFT END BEARING THRUST	
5116198	WASHER	2
9409028	BOLT, 3/8"-16X1" (12.9001)	4
	1.7060 SEAL, CAM AND BALANCER OIL	
5116476	SEAL, OIL (FRONT)	2
	1.7061 SLINGER, CAM AND BALANCER SHAFT OIL	
5134388	SLINGER	2
	1.7062 SPACER, CAM AND BALANCER SHAFT PULLEY	
5121071	SPACER	2
	1.7080 SHAFT, BALANCER	
5121073	SHAFT	1
	1.7130 PULLEY, FRONT BALANCER	
[illegible]	[illegible]	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUAN
		1.7190 WEIGHT, REAR BALANCER	
7C	5119277	WEIGHT (CRESCENT SHAPE, .2391" THICK, 2 HOLES)	
7C	9409028	BOLT, 3/8"-16X1" LOCK (12.9001)	
		1.7200 GEAR, CAMSHAFT AND BALANCER SHAFT	
7A,C	5133387	GEAR (R.H. HELIX) (CAMSHAFT LB-LC-RA-RD, BALANCER LA-LD-RB-RC ENG.)	
7A,C	5133388	GEAR (L.H. HELIX) (CAMSHAFT LA-LD-RB-RC, BALANCER LB-LC-RA-RD ENG.)	
7A	218217	KEY, 3/16"X5/8" WOODRUFF (12.9350)	
7A	5150087	NUT (1.7140)	
		1.7202 SPACER, CAMSHAFT GEAR	
7A	5121077	SPACER	
		1.7207 RETAINER, CAM AND BALANCER SHAFT GEAR NUT	
7A	5172734	RETAINER	
7A	181360	BOLT, 3/8"-24X3/4" (12.9001)	
7A	103321	LOCKWASHER, 3/8" (12.9200)	
		1.7220 GEAR ASSY., IDLER	
		INCLUDES BEARING IN 1.7225.	
7C	5135227	GEAR ASSY. (L.H. HELIX)	
		1.7225 BEARING, IDLER GEAR	
7F	5196793	BEARING	
7F	5132504	WASHER (THRUST)	
		1.7250 HUB, IDLER GEAR	
7F	5124458	HUB	
7F	5157244	BOLT (4.4190)	
		1.7604 GASKET, ACCESSORY DRIVE	
	5117061	GASKET (1.5040)	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTI
		1.7622 ADAPTOR, ACCESSORY DRIVE	
	5122386	ADAPTOR (HYDRAULIC PUMP) (12.5020)	1
	103196	STUD, 3/8"X1 9/16" (12.9117)	2
	103321	LOCKWASHER, 3/8" (12.9200)	2
	117049	NUT, 3/8"-24 HEX. (12.9120)	2
		1.7623 GASKET, ACCESSORY DRIVE ADAPTOR	
	5188755	GASKET, HYDRAULIC PUMP TO ADAPTOR (12.5005)	1
		1.7630 PLATE, ACCESSORY DRIVE	
8A	5170450	PLATE	1
	5140814	SPACER	1
8A	5145091	BOLT, 3/8"-24X1.38" (12.5015)	4
		1.7635 COUPLING, ACCESSORY DRIVE	
	5143616	COUPLING	1
		1.7670 GEAR, ACCESSORY DRIVE	
	5140971	GEAR, HYDRAULIC PUMP DRIVE (12.5030)	1
	455921	PIN, 1/8"X1 1/2" (3.3063)	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTI
		1.8060 ARM ASSY. EXHAUST VALVE	
		INCLUDES ITEMS IN 1.8130, 1.8140, 1.8150 AND 1.8343.	
	5135268	ARM ASSY. (RIGHT)(4 VALVE)	3
	5135267	ARM ASSY. (LEFT)(4 VALVE)	3
		1.8080 ARM ASSY., INJECTOR ROCKER	
		INCLUDES ITEMS IN 1.8110 THRU 1.8150.	
9A	5179954	ARM ASSY.	3
		1.8110 BUSHING, INJECTOR ROCKER ARM-LARGE	
9A	5150318	BUSHING	3
		1.8120 BUSHING, INJECTOR ROCKER ARM-SMALL	
9A	5150311	BUSHING	3
		1.8130 CLEVIS, INJECTOR AND EXHAUST VALVE ROCKER ARM	
9A	5150312	CLEVIS	9
		1.8140 BUSHING, INJECTOR AND EXHAUST VALVE ROCKER ARM CLEVIS	
9A,C	5123700	BUSHING	15
		1.8150 PIN, INJECTOR AND EXHAUST VALVE ROCKER ARM CLEVIS	
9A	5150314	PIN (CLEVIS END)	9
9A,C	5123711	PIN (BRIDGE END)	6
		1.8160 SHAFT, ROCKER	
		A SHAFT ASSY. INCLUDES PLUG IN 1.8160.	
9A	5116072	SHAFT ASSY.	
	5151272	PLUG	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	1.8170 BRACKET, ROCKER SHAFT	
5116128	BRACKET	6
5119198	BOLT	6
	1.8180 ROD, PUSH	
5128640	ROD	9
5151601	LOCKNUT	9
	1.8190 SPRING, PUSH ROD	
5108918	SPRING (2 ORANGE STRIPES) (VALVE AND INJECTOR)	9
	1.8200 SEAT, PUSH ROD SPRING - UPPER	
5108919	SEAT (VALVE AND INJECTOR)	9
	1.8210 SEAT, PUSH ROD SPRING-LOWER	
5123250	SEAT	9
	1.8250 RETAINER, PUSH ROD	
5150303	RETAINER (SNAP RING)	9
	1.8260 FOLLOWER ASSY., CAM	
5115087	FOLLOWER ASSY. (INCLUDES ROLLER SET)	9
	1.8265 ROLLER SET, CAM FOLLOWER	
	INCLUDES ROLLER WITH BUSHING AND PIN.	
5195220	ROLLER SET (STANDARD)	9
	1.8300 GUIDE CAM FOLLOWER	
5116125	GUIDE	3
443603	BOLT, 1/4"-20X3/4" (12.9001)	6
103319	LOCKWASHER, 1/4" (12.9200)	6

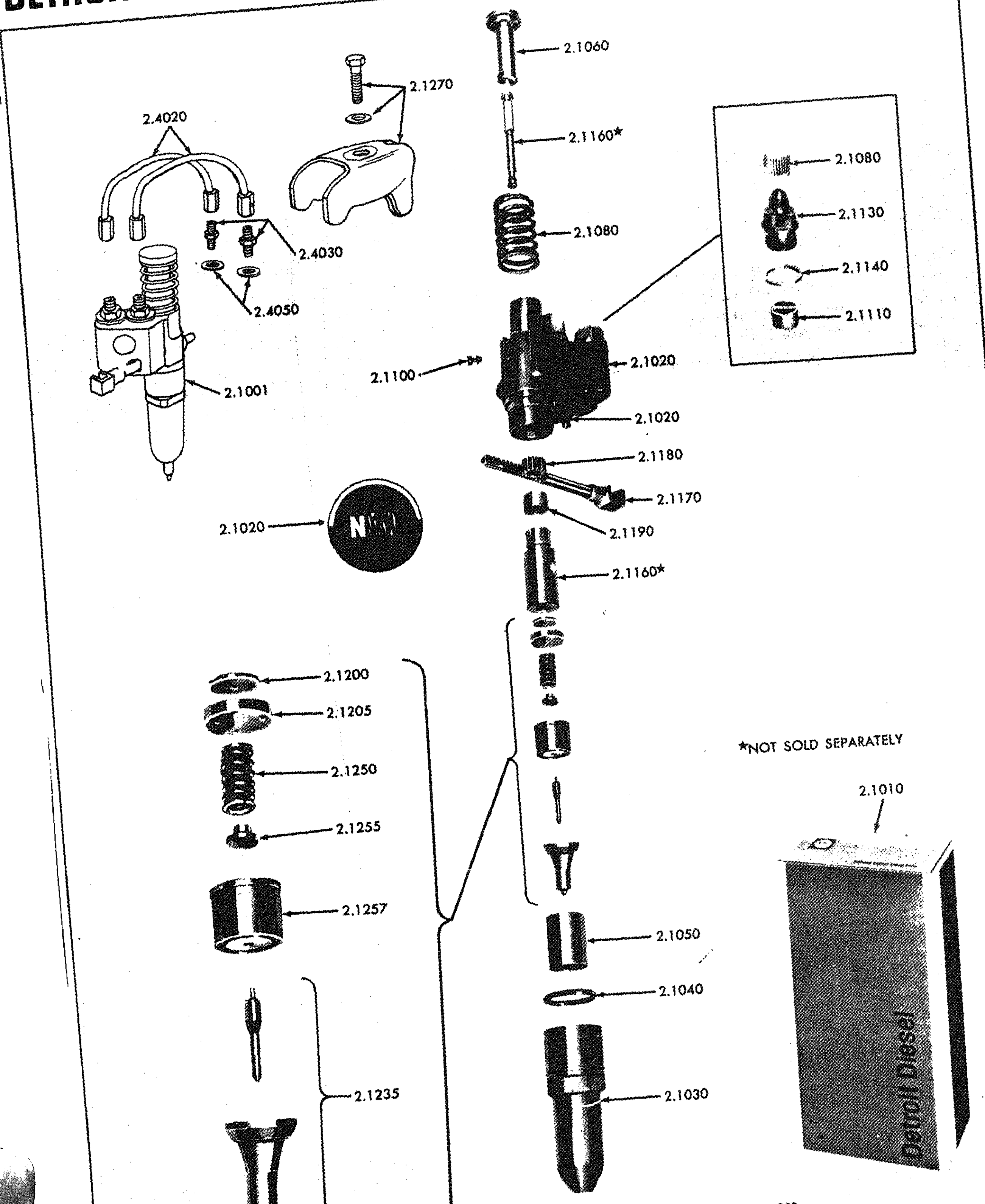
FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION
		1.8310 VALVE, EXHAUST
9C	5199323	VALVE (INCLUDES LOCKS)
		1.8320 GUIDE, EXHAUST VALVE
		A VALVE GUIDE KIT INCLUDES 1-5131961 GUIDE AND 1-5131973 SEAL. INSTALLER (PKG.) CONSISTS OF 100 PIECES.
9C	5131961	GUIDE
	5198529	KIT, VALVE GUIDE AND SEAL
	5131973	SEAL, VALVE GUIDE (USE WITH 5131961)
	5199912	INSTALLER, EXHAUST VALVE SEAL (4 VALVE)
		1.8330 INSERT, EXHAUST VALVE
9C	5116361	INSERT (STANDARD)
9C	5196752	INSERT (.010" OVERSIZE ON O.D.)
		1.8340 SPRING, EXHAUST VALVE
9C	5144019	SPRING (RED AND GREEN STRIPE)
		1.8343 BRIDGE, EXHAUST VALVE
9C	5135262	BRIDGE
		1.8350 CAP, EXHAUST VALVE SPRING
9C	5123330	CAP
		1.8360 SEAT, EXHAUST VALVE SPRING
	5111467	SEAT (0.60" THICK)
		1.8370 LOCK, EXHAUST VALVE SPRING
9C	5116341	LOCK (HALVES)
		1.8450 COVER, ROCKER
9D	5125355	COVER, (ITEM 2) (Y-6")

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		1.8455 GASKET, ROCKER COVER	
9D	5147994	GASKET	1
		1.8460 BOLT, ROCKER COVER	
9D	5100104	SCREW ASSY.	4

GROUP NOMENCLATURE

1.0000	ENGINE (less major assemblies)
1.1000	Cylinder Block
1.1000A	Air Box Drains
1.2000	Cylinder Head
1.2000A	Engine Lifter Bracket
1.3000	Crankshaft, Oil Seals and stabilizers
1.3000A	Crankshaft Front Cover
1.3000C	Crankshaft Pulley
1.3000D	Crankshaft Pulley Belt
1.4000A	Flywheel
1.5000A	Flywheel Housing
1.6000	Connecting Rod and Piston
1.7000	Camshaft and Gear Train
1.7000A	Balance Weight Cover
1.7000B	Accessory Drive
1.8000	Valve and Injector Operating Mechanism
1.8000A	Rocker Cover
2.0000	FUEL SYSTEM
2.1000A	Fuel Injector
2.2000	Fuel Pump
2.2000A	Fuel Pump Drain
2.3000A	Fuel Filter
2.4000	Fuel Manifold and/or Connections
2.5000A	Fuel Lines and Fuel Cooler
2.7000A	Mechanical Governor
2.9000	Injector Controls
2.9000A	Throttle Controls
3.0000	AIR SYSTEM
3.3000A	Air Inlet Housing
3.4000	Blower
3.4000A	Blower Drive Shaft
3.4000B	Blower End Plate Cover
4.0000	LUBRICATING SYSTEM
4.1000A	Oil Pump
4.1000B	Oil Distribution System
4.1000C	Oil Pressure Regulator
4.2000A	Oil Filter
4.3000A	Oil Filter Lines
4.4000A	Oil Cooler
5.0000	COOLING SYSTEM
5.1000	Fresh Water Pump
5.1000A	Fresh Water Pump Cover
5.2000A	Water Outlet Manifold and/or Elbow
5.2000B	Thermostat
5.2000C	Water By-pass Tube
5.3000B	Water Connections
5.4000A	Fan
6.0000	EXHAUST SYSTEM
6.1000A	Exhaust Manifold
6.2000A	Exhaust Muffler and/or Connections
7.0000	ELECTRICAL—INSTRUMENTS
7.1000A	Battery Charging Generator
7.3000A	Starting Motor

DETROIT DIESEL



*NOT SOLD SEPARATELY

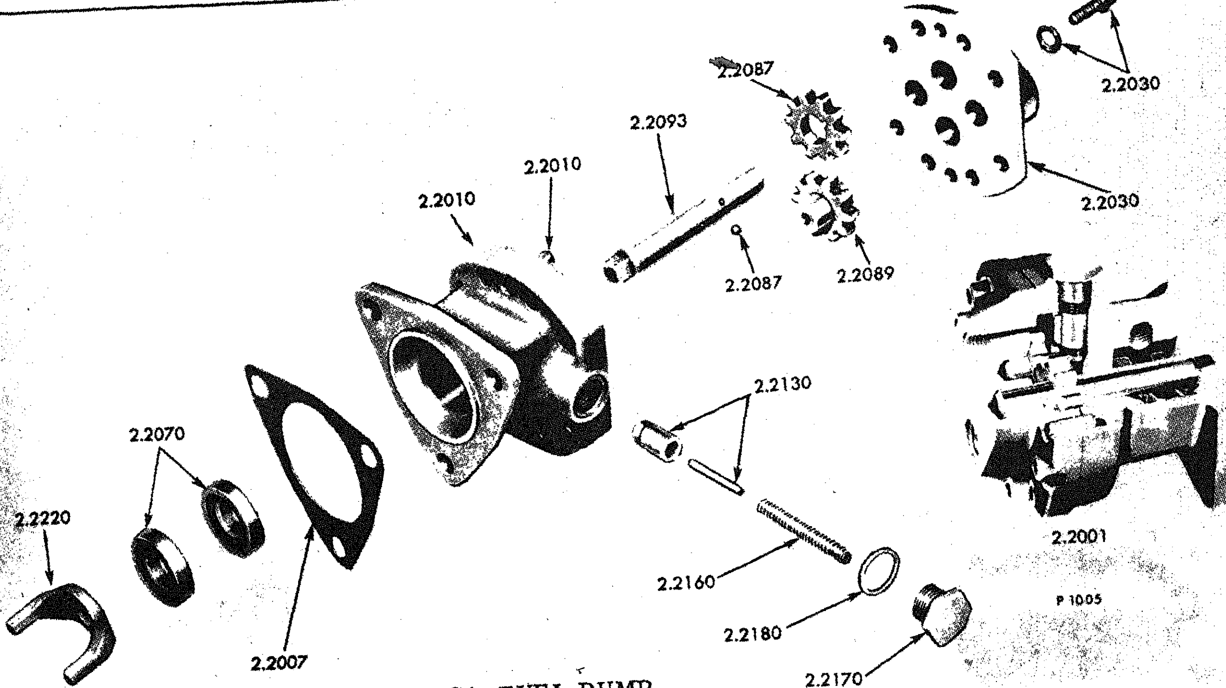


FIG. 2A FUEL PUMP

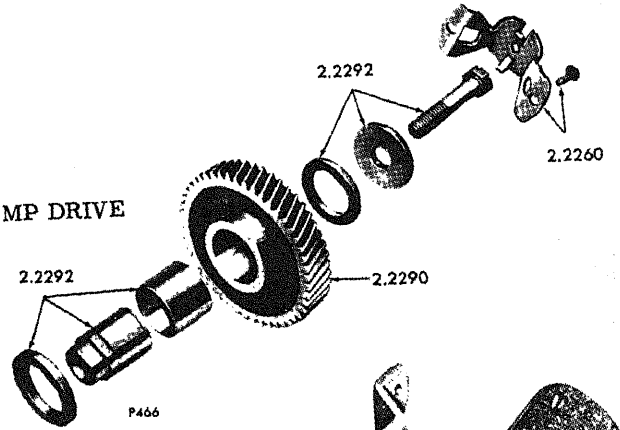


FIG. 2B FUEL PUMP DRIVE

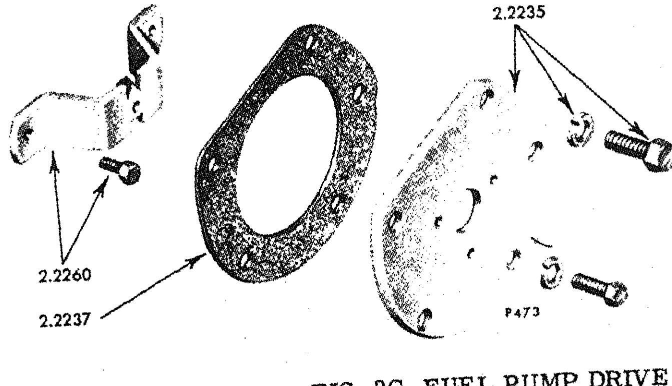


FIG. 2C FUEL PUMP DRIVE

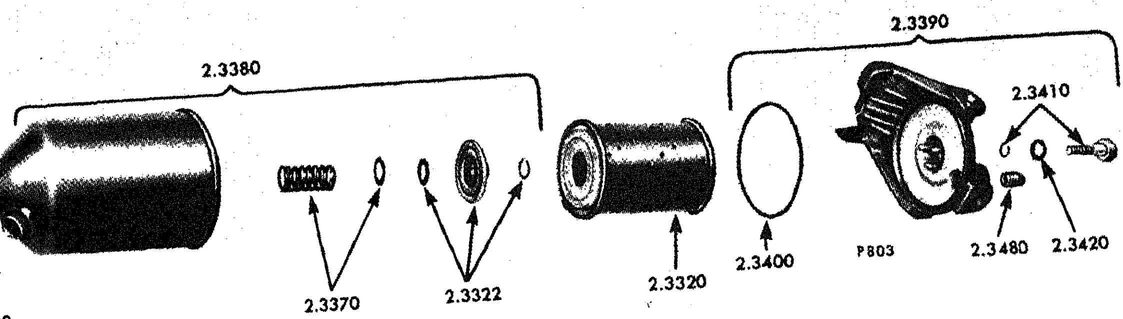


FIG. 3B FUEL FILTER (Canister Type Element)

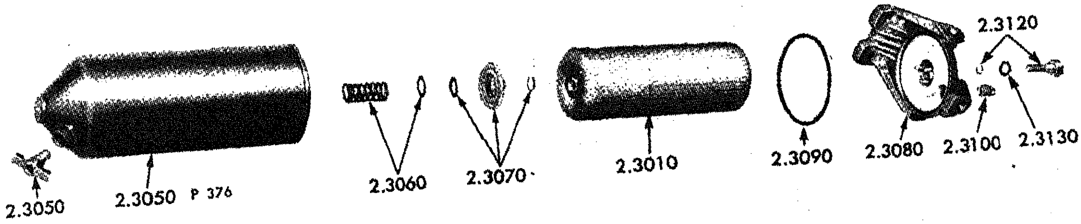
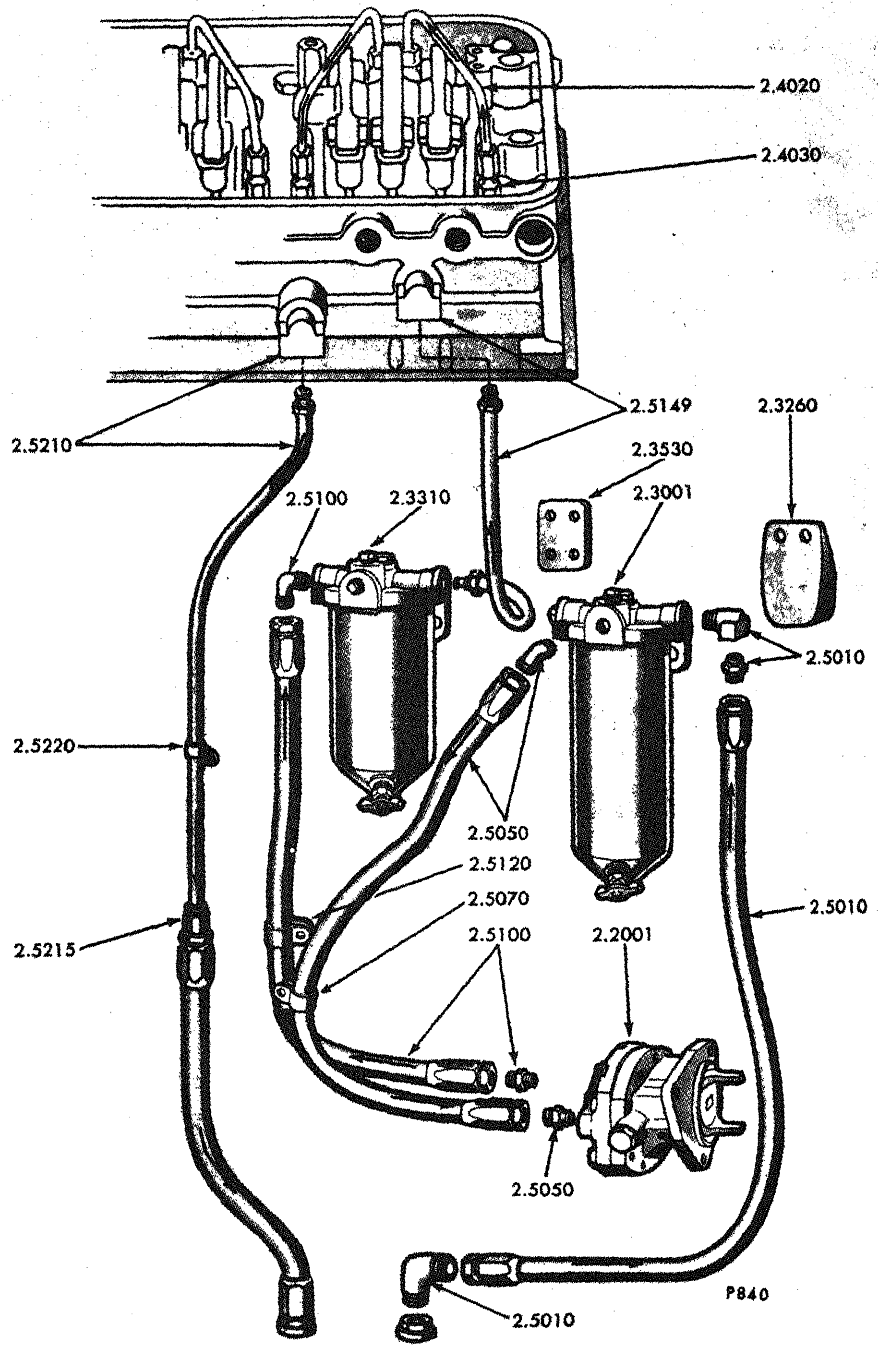


FIG. 3C FUEL STRAINER (Stock Type Element)


2.4020
2.4030
2.5149
2.3260
2.5210
2.3530
2.5100
2.3310
2.3001
2.5010
2.5220
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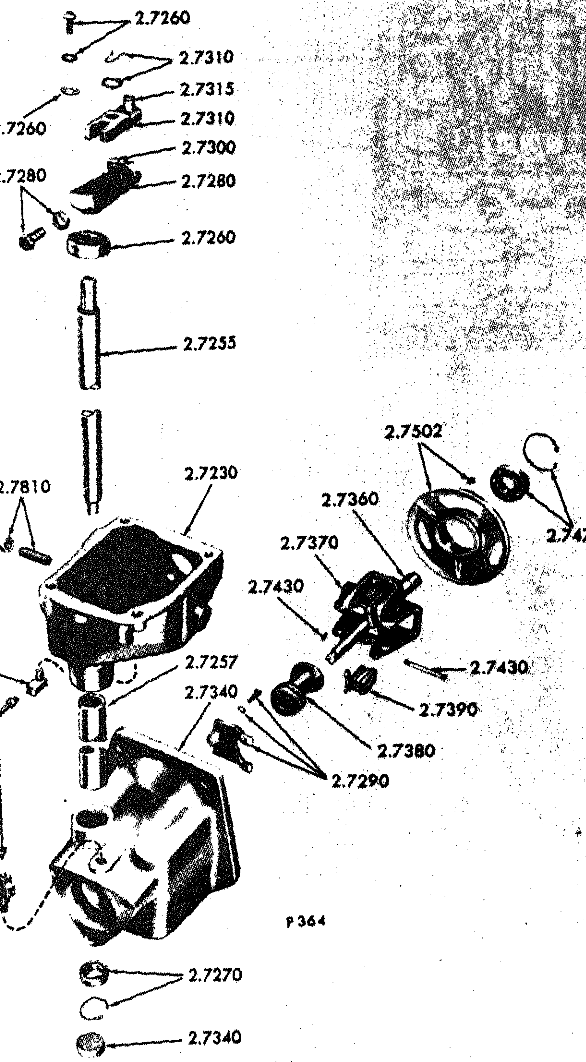
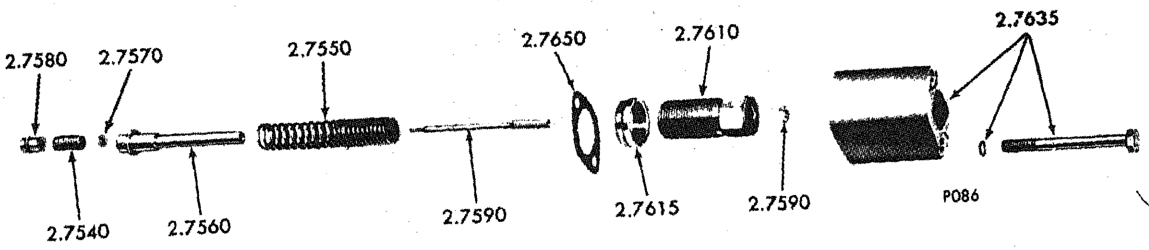
2.5120
2.5070
2.5010
2.5215
2.5100
2.2001
2.5050
P840
2.5010



MECHANICAL GOVERNOR HOUSING
HTS AND LEVER (Closed Linkage)



INDUSTRIAL TYPE

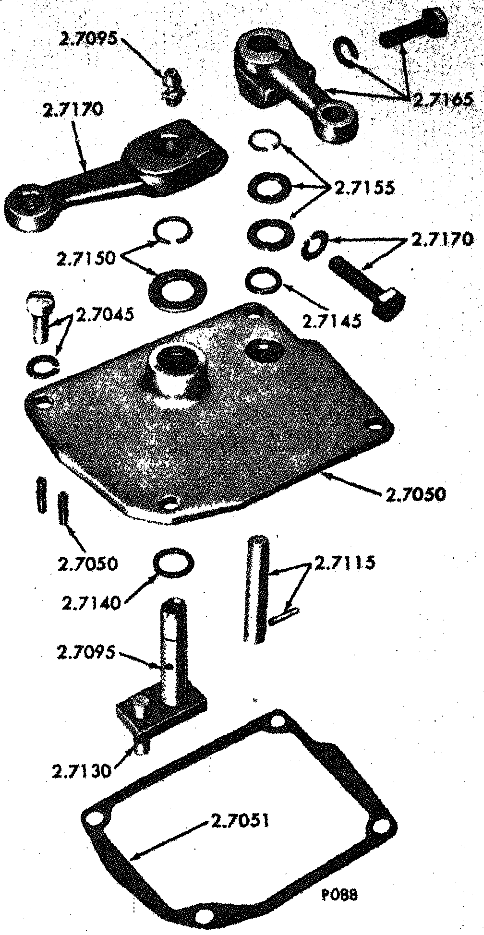


FIG. 5H MECHANICAL GOVERNOR COVER (Double Lever)

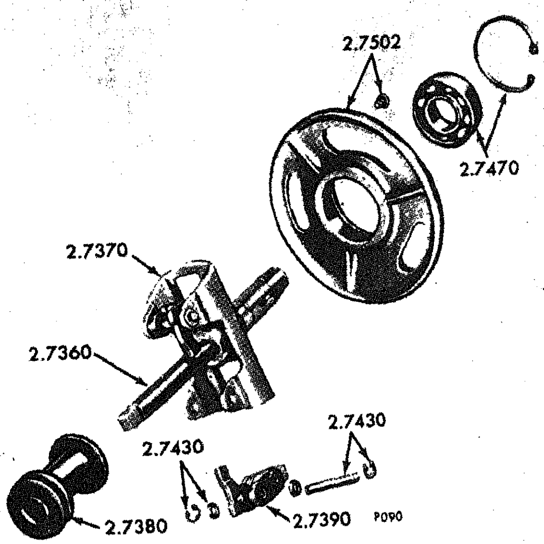


FIG. 5L GOVERNOR WEIGHT SHAFT AND CARRIER

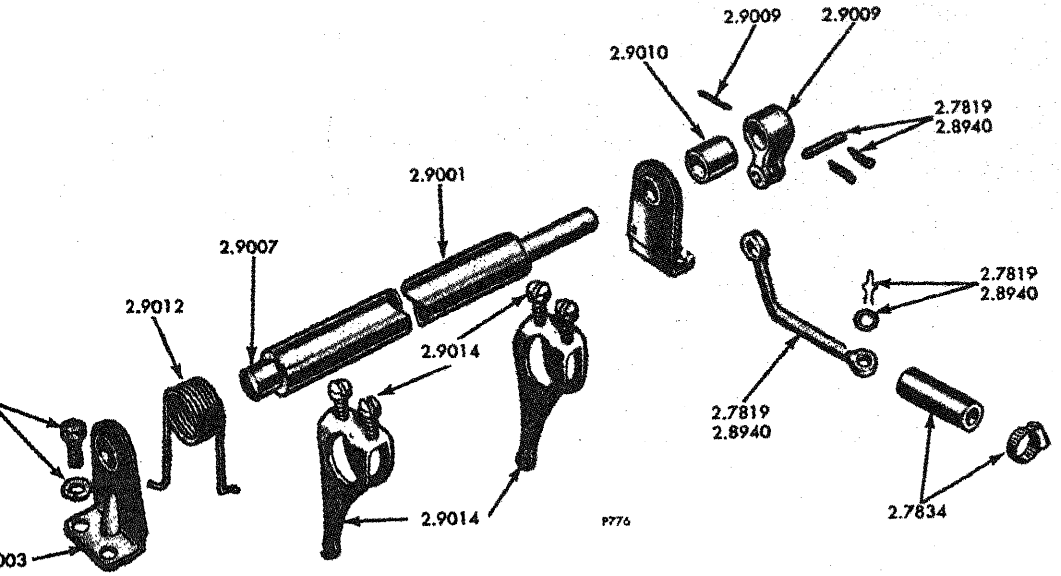


FIG. 7A INJECTOR CONTROL TUBE (Inline Engine)

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.1001 INJECTOR ASSY.	
		FOR TYPE 104 USE TYPE 93. QUANTITIES SHOWN ARE PER CYLINDER. INCLUDES ITEMS IN 2.1020 THRU 2.1265.	
1B	5228773	* INJECTOR ASSY (N45) * THESE INJECTORS HAVE FILTER ELEMENT AT FUEL INLET SIDE ONLY.	1
		2.1002 OVERHAUL KIT, INJECTOR	
		OVERHAUL KIT CONSISTS OF ONE (1) SEAL RING, TWO (2) FILTER CAP GASKETS, TWO (2) FILTER ELEMENTS AND TWO (2) SHIPPING CAPS.	
	5228701	OVERHAUL KIT	AR
		2.1020 BODY ASSY., INJECTOR A BODY ASSY. INCLUDES DOWEL AND PLUG IN 2.1020.	
1B	5228583	BODY ASSY.	1
1B	5226416	DOWEL	1
	5226912	PLUG, BODY	2
1B	5228764	TAG, NUMBER (N45)	1
		2.1030 NUT, INJECTOR VALVE	
1B	5228601	NUT	1
		2.1040 RING, INJECTOR SEAL	
1B	5229167	RING	1
		2.1050 DEFLECTOR, INJECTOR SPILL	
1B	5228109	DEFLECTOR	1
		2.1060 FOLLOWER, INJECTOR	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.1080 SPRING, INJECTOR PLUNGER	
5228739	SPRING	1
	2.1100 PIN, INJECTOR STOP	
5228608	PIN	1
	2.1110 ELEMENT, INJECTOR FILTER	
5228587	ELEMENT	1
	2.1130 CAP, INJECTOR FILTER	
5228588	CAP	2
	2.1140 GASKET, INJECTOR FILTER CAP	
5226186	GASKET	2
	2.1150 CAP, INJECTOR SHIPPING	
5226414	CAP	AR
	2.1160 PLUNGER AND BUSHING ASSY., INJECTOR	
	PLUNGERS AND BUSHINGS ARE NOT SOLD SEPARATELY. AN ASSY. INCLUDES PIN IN 2.1165.	
5228684	PLUNGER AND BUSHING ASSY. (N45)	1
	2.1165 PIN, BUSHING GUIDE	
5226393	PIN	1
	2.1170 RACK, INJECTOR	
5226719	RACK	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.1190 RETAINER, INJECTOR GEAR	
1B	5228586	RETAINER	1
		2.1200 VALVE, INJECTOR CHECK	
1B	5228694	VALVE	1
		2.1205 CAGE, INJECTOR, CHECK VALVE	
1B	5228696	CAGE	1
		2.1235 TIP ASSY., INJECTOR SPRAY	
		COMPONENTS OF TIP ASSY. ARE NOT SOLD SEPARATELY.	
1B	5229[illegible]	TIP ASSY. (M65, N40, N45, N50,)	1
		2.1238 VALVE KIT, INJECTOR	
		INCLUDES ITEMS IN 2.1250 AND 2.1255.	
	52287[illegible]9	VALVE KIT (SHORT QUILL NEEDLE)	[illegible]
		2.1250 SPRING, INJECTOR VALVE	
1B	52285[illegible]	SPRING	[illegible]
		2.1255 SEAT, INJECTOR VALVE SPRING	
1B	5228766	SEAT	1
		2.1257 CAGE, INJECTOR VALVE SPRING	
1B	5228594	CAGE	1
		2.1270 CLAMP, INJECTOR	
1B	5121259	CLAMP	1

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.2001 PUMP ASSY., FUEL	
	SEE ASSEMBLY BREAKDOWN AS INDICATED BELOW. A FUEL PUMP KIT INCLUDES A 3/8" INLET PUMP, GASKET IN 2.2007 AND REDUCING BUSHING IN 2.2030.	
5146341	# PUMP ASSY. (L.H.) (3/8" INLET)	1
5199560	PUMP KIT, FUEL (L.H.) (PAGE B5)	1
5118219	BOLT, 5/16"-18X7/8" (W/LW)	3
	#NOT SERVICED: COMPONENTS ARE AVAILABLE. FOR COMPLETE REPLACEMENT USE PUMP KIT SHOWN IN SAME TYPE.	
	2.2004 OVERHAUL KIT, FUEL PUMP	
5195078	& OVERHAUL KIT	AR
	& INCLUDES ITEMS IN 2.2007, 2.2070, 2.2089, 2.2093, 2.2130, 2.2160 AND 2.2180.	
	2.2007 GASKET, FUEL PUMP TO ENGINE	
5150193	GASKET (5.1010)	1
	2.2230 COUPLING, FUEL PUMP DRIVE	
5154216	COUPLING	1
	A 2.2001 PUMP ASSY., FUEL	
5146341	= PUMP ASSY. (L.H.) (3/8" INLET) (5199560)	1
	= NOT SERVICED: USE PART NUMBER IN PARENTHESES.	
	2.2010 BODY, FUEL PUMP	
5146337	BODY	1
141195	PIN, 1/4"X5/8" DOWEL (12.9290)	2
	2.2030 OVER, FUEL PUMP	
5134560	COVER	1
3719219	BOLT, 1/4"-20X3/4" (WITH LOCKWASHER)	8

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.2070 SEAL, FUEL PUMP OIL	
2A	5230007	SEAL	2
		2.2087 GEAR, FUEL PUMP (DRIVE)	
	5174975	GEAR	1
	147481	BALL, 1/8" DIA STEEL (12.9670)	1
		2.2089 SHAFT, FUEL PUMP DRIVEN	
		A SHAFT ASSY. INCLUDES GEAR WHICH IS NOT SOLD SEPARATELY.	
2A	5181747	SHAFT ASSY.	1
		2.2093 SHAFT, FUEL PUMP	
		A SHAFT ASSY. INCLUDES SHAFT IN 2.2093 AND ITEMS IN 2.2087.	
2A	5181746	SHAFT ASSY. (DRIVE)	1
		2.2130 VALVE, FUEL PUMP	
2A	5174973	VALVE	1
2A	103709	PIN, 5/32"X1" STRAIGHT (12.9300)	1
		2.2160 SPRING, FUEL PUMP VALVE RETAINING	
2A	5184530	SPRING	1
		2.2170 PLUG, FUEL PUMP VALVE	
2A	5174971	PLUG	1
		2.2180 GASKET, FUEL PUMP VALVE PLUG	
2A	5161003	GASKET	1
		2.2001 PUMP ASSY. - FUEL	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.2007 GASKET, FUEL PUMP TO ENGINE	
5150193	GASKET	1
	2.2010 BODY, FUEL PUMP	
5146337	BODY	1
5145009	PLUG, 1/8" PIPE (12.9550)	2
141195	PIN, 1/4" X 5/8" DOWEL (12.9290)	2
	2.2030 COVER, FUEL PUMP	
5134560	COVER	1
5198558	BUSHING, 3/8" X 3/4"	1
3719219	BOLT, 1/4"-20X3/4" (WITH LOCKWASHER)	8
	2.2070 SEAL, FUEL PUMP OIL	
5230007	SEAL	2
	2.2087 GEAR, FUEL PUMP (DRIVE)	
5174975	GEAR	1
147481	BALL, 1/8" DIA STEEL (12.9670)	1
	2.2089 SHAFT, FUEL PUMP DRIVEN	
	A SHAFT ASSY. INCLUDES GEAR WHICH IS NOT SOLD SEPARATELY.	
5181747	SHAFT ASSY.	1
	2.2093 SHAFT, FUEL PUMP	
	A SHAFT ASSY. INCLUDES SHAFT IN 2.2093 AND ITEMS IN 2.2087.	
5181746	SHAFT ASSY. (DRIVE)	1
5178700	SHAFT (DRIVE)	1
	2.2130 VALVE, FUEL PUMP	
5174973	VALVE	1
103709	PIN, 5/32"X1" STRAIGHT (12.9300)	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.2160 SPRING, FUEL PUMP VALVE RETAINING	
2A	5184530	SPRING	1
		2.2170 PLUG, FUEL PUMP VALVE	
2A	5174971	PLUG	1
		2.2180 GASKET, FUEL PUMP VALVE PLUG	
2A	5161003	GASKET	1

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.3001 STRAINER ASSY., FUEL	
	SEE ASSEMBLY BREAKDOWN BELOW.	
5575568	STRAINER ASSY. (6") (T-60)	1
5575197	DECAL (WITH 5575568 STRAINER)	1
5145010	PLUG, 1/4" PIPE (12.9550)	2
	2.3310 FILTER ASSY., FUEL	
	SEE ASSEMBLY BREAKDOWN PAGE B9	
5573949	FILTER ASSY. (4") (T-58)	1
5574083	DECAL	1
5145010	PLUG, 1/4" PIPE (12.9550)	2
181374	BOLT, 3/8"-24X1 1/2" (12.9001)	2
103321	LOCKWASHER, 3/8" (12.9200)	2
117049	NUT, 3/8"-24 HEX (12.9120)	2
	C 2.3001 STRAINER ASSY., FUEL	
5575568	STRAINER ASSY. (6" SOCK TYPE) (T-60)	1
	2.3010 ELEMENT, FUEL STRAINER (PRIMARY)	
5574961	ELEMENT (6", FELT SOCK TYPE, T-553) (INCLUDES GASKET IN 2.3090 AND 2.3130)	1
	2.3050 SHELL, FUEL STRAINER (PRIMARY)	
5577586	SHELL (2.3380)	1
103647	DRAINCOCK, 1/4" (12.9510)	1
	2.3080 COVER, FUEL STRAINER (PRIMARY)	
6436253	COVER ASSY. (IDENTIFIED WITH CAST "P") (INCLUDES ITEMS IN 2.3090, 2.3120 and 2.3130)	1
	2.3090 GASKET, FUEL STRAINER COVER	
5574161	GASKET (2.3400)	1

IG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.3100 PLUG, FUEL STRAINER COVER	
C	5145010	PLUG, 1/4" PIPE (TEFLON WRAPPED) (12.9550)	2
C	5145011	PLUG, 3/8" PIPE (12.9550)	2
		2.3120 SCREW, FUEL STRAINER COVER	
	6435793	BOLT (USE WITH COVER MARKED "P")	1
		2.3130 GASKET, FUEL STRAINER COVER SCREW	
	6435794	GASKET (USE WITH COVER MARKED "P")	1
		2.3310 FILTER ASSY., FUEL	
B	5573949	FILTER ASSY. (4") (T-58)	1
		2.3320 ELEMENT, FUEL FILTER (SECONDARY)	
B	5573261	ELEMENT (4", TP-509) (INCLUDES GASKETS IN 2.3400, 2.3420)	1
		2.3322 SEAT, FUEL FILTER ELEMENT	
B	5574123	SEAT	1
B	5574126	SEAL	1
B	5574120	RETAINER (RING)	1
		2.3370 SPRING, FUEL FILTER ELEMENT	
B	5574124	SPRING	1
B	5574122	SEAT, SPRING (WASHER)	1
		2.3380 SHELL, FUEL FILTER (SECONDARY)	
B	5574125	SHELL, ASSY. (INCLUDES ITEMS IN 2.3322 AND 2.3370)	1
		2.3390 COVER, FUEL FILTER (SECONDARY)	
B	6436254	COVER ASSY. (IDENTIFIED WITH CAST	1

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.3400 GASKET, FUEL FILTER COVER TO SHELL	
5574161	GASKET	1
	2.3410 SCREW, FUEL FILTER COVER	
5574118	SCREW	1
	2.3420 GASKET, FUEL FILTER COVER SCREW	
1503536	GASKET (2.3110)	1
	2.3480 PLUG, FUEL FILTER	
5145010	PLUG, 1/4" PIPE (IN COVER) (12.9550)	2
	2.3500 DRAINCOCK, FUEL FILTER	
103647	DRAINCOCK, 1/4" (12.9510)	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.4020 PIPE, FUEL	
	5116204	PIPE ASSY. (INLET AND OUTLET)	6
		2.4030 CONNECTOR, FUEL PIPE	
	5152138	CONNECTOR	6
		2.4050 WASHER, FUEL PIPE CONNECTOR	
	5152148	WASHER	6

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.5006 VALVE, FUEL SUPPLY CHECK	
5122279	VALVE, 1/4" SPRING TYPE	AR
	2.5100 TUBE, FUEL PUMP TO FILTER	
5121080	TUBE ASSY. (DEV. L. 15.88")	1
137407	CONNECTOR, 3/8" INV. FL. TUBE (12.9460)	1
137423	ELBOW, 3/8" INV. FL. TUBE 90 DEG (12.9480)	1
	2.5120 CLIP, FUEL PUMP TO FILTER TUBE	
5177623	CLIP (3/8" TUBE)	1
	2.5151 TUBE, FILTER OUTLET	
5125318	TUBE ASSY. (DEV. L. 19 3/16")	1
143338	ELBOW, 3/8" INV. FL. TUBE 45 DEG (12.9480)	2
	2.5210 TUBE, FUEL DRAIN	
5116440	ELBOW, RESTRICTED	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.7001 GOVERNOR ASSY.	
		A GOVERNOR ASSY. INCLUDES ITEMS IN 2.7002, 2.7045, THRU 2.7810 EXCEPT 2.7165, 2.7520, 2.7530, AND 2.7740.	
	5129802	GOVERNOR ASSY. (LIMITING)	1
	180083	BOLT, 5/16"-18X1 1/2" (12.9001)	2
	9414285	BOLT, 3/8"-24X7/8" (12. PT. HD.) (12.9001)	3
	5145225	WASHER, 3/8" COPPER (12.9190)	3
	9414322	WASHER, 3/8" FLAT (12.9190)	2
	103320	LOCKWASHER, 5/16" (12.9200)	2
		2.7002 NAME PLATE, GOVERNOR	
	5122166	NAME PLATE	1
	109371	SCREW, #9X3/16" RED. HD. DR.	2
		2.7010 GASKET, GOVERNOR TO ENGINE	
	5116336	GASKET	1
		2.7045 COVER ASSY., GOVERNOR (COMPLETE)	
		SEE ASSEMBLY BREAKDOWN AS INDICATED.	
	5126428	COVER ASSY. (LIMITING) (C & D ENG.) (PAGE B18)	1
	5126792	SCREW, 1/4"-20X3/4" FIL. HD. (GROOVED FOR TORSION SPRING)	1
5H	271468	SCREW, 1/4"-20X3/4" FIL. HD. (WITH LOCKWASHER) (12.9010)	4
	120380	LOCKWASHER, 1/4" (12.9200)	5
		2.7051 GASKET, GOVERNOR COVER	
5H	5122742	GASKET	1
		2.7165 LEVER, GOVERNOR COVER SHUTDOWN SHAFT	
5H	5183042	LEVER (2.9410)	1

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.7170 LEVER, GOVERNOR COVER THROTTLE SHAFT	
5120069	LEVER (2.9340)	1
213546	BOLT, 1/4"-20X1" (12.9001)	1
120380	LOCKWASHER, 1/4" (12.9200)	1
	2.7230 HOUSING, GOVERNOR CONTROL	
5144090	HOUSING (C & D ENGINES)	1
5116262	ADAPTOR, INJECTOR CONTROL LINK BOOT (2.7830)	1
5145009	PLUG, 1/8" PIPE	1
	2.7250 SHAFT ASSY., GOV. OPERATING	
	INCLUDES ITEMS IN 2.7255, 2.7280, 2.7300, AND BEARING IN 2.7260.	
5122752	SHAFT ASSY. (C AND D ENGINE)	1
	2.7255 SHAFT, GOV. OPERATING	
5122751	SHAFT	1
	2.7257 TUBE, GOV. OPEATING SHAFT	
5122754	TUBE	1
	2.7260 BEARING, GOV. OPERATING SHAFT (UPPER)	
9431894	BEARING	1
9421917	SCREW AND LOCKWASHER ASSY. #10-24X7/16" (12.9025)	1
	2.7270 BEARING, GOV. OPERATING SHAFT (LOWER)	
9431887	BEARING	1
9413284	RING, SNAP (TO HOUSING)	1

IG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.7280 LEVER, GOV. OPERATING SHAFT	
		A LEVER ASSY. INCLUDES PIN IN 2.7300.	
5D	5122749	LEVER ASSY. (C & D ENG.)	1
5D	5150898	SCREW (GAP ADJUSTING)	1
5D	122161	NUT, 1/4"-28 HEX. (12.9120)	1
		2.7290 FORK, GOV. OPERATING SHAFT	
5D	5122741	FORK	1
5D	9425382	SCREW, #10-32X5/8" (W/LW) (12.9001)	2
		2.7300 PIN, GOVERNOR OPERATING SHAFT LEVER	
5D	5122746	PIN	1
		2.7310 LEVER, GOV. DIFFERENTIAL	
		A LEVER ASSY. INCLUDES PIN IN 2.7315	
5D	5126311	LEVER ASSY. (LIMITING SPEED)	1
5D	5150941	WASHER	1
	9421917	SCREW AND LOCKWASHER ASSY	1
	120391	WASHER, 7/32"-1/2" FLAT	1
5D	142583	RETAINER, 13/64" SPRING (12.9640)	1
		2.7315 PIN, GOV. DIFFERENTIAL LEVER	
5D	5126310	PIN (LIMITING SPEED)	1
		2.7340 HOUSING, GOVERNOR WEIGHT	
5D	5129730	HOUSING (C AND D ENGINE)	1
	5119127	BUSHING (WEIGHT SHAFT END)	1
5D	9428477	PLUG, CUP (15/16" DIA.) (3.4030)	1
		2.7350 SHAFT AND CARRIER ASSY., GOVERNOR WEIGHT	
		SEE ASSEMBLY BREAKDOWN PAGE B19.	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.7475 SPACER, GOVERNOR WEIGHT CARRIER SHAFT	
5122738	SPACER (BETWEEN GEAR AND BEARING)	1
	2.7540 SPRING, GOVERNOR LOW SPEED	
5183704	SPRING (2 YELLOW STRIPES)	1
	2.7550 SPRING, GOVERNOR HIGH SPEED	
5182560	SPRING (WIDE RED STRIPE)	1
	2.7560 PLUNGER, GOVERNOR LOW SPEED SPRING	
5182555	PLUNGER	1
	2.7570 SEAT, GOV. LOW SPEED SPRING	
5150892	SEAT	1
	2.7580 CAP, GOV. LOW SPEED SPRING	
5150899	CAP	1
	2.7590 SCREW, GOVERNOR LOW SPEED SPRING ADJUSTING	
5101432	PIN	1
122161	NUT, 1/4"-28 HEX (12.9190)	1
5102270	SCREW	1
	2.7610 RETAINER, GOVERNOR HIGH SPEED SPRING	
5182557	RETAINER	1
	2.7615 LOCKNUT, GOVERNOR HIGH SPEED SPRING RETAINER	
5186115	LOCKNUT	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.7635 HOUSING, GOVERNOR LIMITING SPEED SPRING	
5G	5182559	HOUSING	1
	445520	BOLT, 5/16"-18X3 1/2" (12.9001)	2
	103320	LOCKWASHER 5/16" (12.9200)	2
		2.7650 GASKET, GOVERNOR HIGH SPEED SPRING COVER	
5G	5152944	GASKET	1
		2.7810 SCREW ASSY., GOV. BUFFER	
5D	5177083	SCREW ASSY. (INCLUDES SPRING)	1
	124925	NUT (3/8"-24 HEX.) (12.9120)	1
		2.7819 ROD ASSY. GOV. TO INJECTOR LINK	
7A	5122797	LINK (A & C ENG.)	1
7A	5122798	LINK (B & D ENG.)	1
	142583	RETAINER, SPRING 13/64" (12.9640)	1
7A	114783	PIN (1/4"X51/64" CLEVIS) (12.9260)	1
7A	103361	PIN, 1/61"X1/2" COTTER (12.9250)	1
	5150941	WASHER (2.7310)	1
		2.7830 ADAPTOR, CYLINDER HEAD GOVERNOR CONTROL LINK	
4A	5116262	ADAPTOR (IN HEAD) (PLAIN END)	1
		2.7834 BOOT, GOV. TO INJECTOR LINK	
	5199773	# HOSE (7/8" I.D. X1.26"L) (A & C ENG.)	1
	272855	CLAMP, HOSE (SPRING, 1 1/4") (A & C ENG.) (12.9660)	2
		# STD. LENGTH HOSE. CUT TO LENGTH SHOWN.	
		2.7890 TUBE ASSY., GOVERNOR LUBRICATION	
	5129726	TUBE ASSY. (DEV. L. 11.36") (WEIGHT HOUSING)	1

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.7945 SEAL, GOVERNOR	
101140	SEAL	AR
	2.7960 GEAR, GOVERNOR DRIVE	
116026	GEAR (L.H. HELIX) (RC, RD, LA, LB)	1
24546	KEY, 5/32"X5/8" WOODRUFF (12.9350)	1
434177	NUT, 5/8"-18 LOCK (12.9140)	1
	2.7045 COVER ASSY., GOVERNOR (COMPLETE)	
126428	COVER ASSY. (C AND D ENGINE, LIMITING SPEED)	1
	2.7050 COVER ASSY., GOV. (LESS SHAFT AND LEVER)	
	INCLUDES ITEMS IN 2.7050, 2.7093 AND 2.7100.	
126397	COVER ASSY. (C AND D ENGINE, LIMITING SPEED)	1
56540	PIN, 3/16" X 5/8" ROLL (12.9275)	2
	2.7095 SHAFT ASSY., GOVERNOR THROTTLE	
	A SHAFT ASSY. INCLUDES ITEMS IN 2.7095. PIN NOT SOLD SEPARATELY.	
126402	SHAFT ASSY.	1
55734	PIN, 1/8"X3/4" SPRING (12.9300)	1
71287	FITTING, 1/8" LUBE (12.9540)	1
	2.7115 SHAFT ASSY., GOVERNOR SHUTDOWN	
26404	SHAFT ASSY. (INCLUDES PIN) (2.7053)	1
3676	PIN, 1/8"X1" ROLL (12.9275)	1
	2.7140 WASHER, GOVERNOR THROTTLE SHAFT (PACKING)	
79232	SEAL RING (2.4225)	1
44196	WASHER, SEAL RING BACK-UP (2.7045)	1

G	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.7145 WASHER, GOVERNOR SHUTDOWN SHAFT (PACKING)	
	5182977	SEAL RING (3.3055)	1
		2.7150 RETAINER, GOVERNOR THROTTLE SHAFT PACKING	
.	5150238	WASHER (3.4001)	1
	5122732	RING, SNAP	1
		2.7155 RETAINER, GOVERNOR SHUTDOWN SHAFT PACKING	
.	5151487	WASHER (2.7430)	1
.	5178581	RING, SNAP (2.7430)	1
	5144178	WASHER (DISHED)	1
		2.7350 SHAFT AND CARRIER ASSY., GOVERNOR WEIGHT	
	5100061	SHAFT AND CARRIER ASSY.	1
		2.7360 SHAFT, GOVERNOR WEIGHT CARRIER	
L	5196855	SHAFT ASSY. (INCLUDES SHAFT AND CARRIER) (LIMITING SPEED)	1
		2.7380 RISER, GOVERNOR	
L	5109544	RISER (INCLUDES THRUST BEARING) (SMALL FLANGE)	1
		2.7390 WEIGHT, GOVERNOR	
L	5122776	WEIGHT (LOW SPEED)	2
L	5129721	WEIGHT (HIGH SPEED)	2
		2.7430 PIN, GOVERNOR WEIGHT	
D	9411504	RING, SNAP	4

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.7470 BEARING, GOVERNOR WEIGHT CARRIER SHAFT (CONT.)	
9411502	RING, SNAP	1
	2.7502 SUPPORT, GOVERNOR WEIGHT SHAFT BEARING	
5122783	SUPPORT	1

IG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		2.9001 TUBE AND LEVER ASSY., INJECTOR CONTROL	
		A TUBE ASSY. INCLUDES ONE (1) BRACKET IN 2.9003 AND ITEMS IN 2.9007 THRU 2.9010.	
A	5195968	TUBE ASSY. (C ENGINE)	1
		2.9003 BRACKET, INJECTOR CONTROL TUBE	
A	5116264	BRACKET	2
A	9422203	BOLT, 1/4"-20X5/8" (12 PT. HD.)	4
		2.9007 SHAFT, INJECTOR CONTROL TUBE END	
A	5150259	SHAFT (1 1/16" L.)	1
		2.9009 LEVER, INJECTOR CONTROL TUBE	
A	5116267	LEVER	1
A	142486	PIN, 1/8" X 3/4" GROOVE (12.9270)	1
		2.9010 SPACER, INJECTOR CONTROL TUBE LEVER	
A	5116266	SPACER	1
		2.9012 SPRING, INJECTOR CONTROL TUBE	
A	5116265	SPRING	1
		2.9014 LEVER, INJECTOR CONTROL TUBE RACK	
A	5115322	LEVER	3
A	5176228	SCREW	6
		2.9422 WIRE, GOVERNOR CONTROL	
	5146238	* WIRE ASSY. (50" L.) (3.3250)	1
	5184255	PLATE, NAME	1
	110730	LOCKWASHER, 3/8" (12.9200)	1
	122236	NUT, 3/8"-24 HEX. (12.9120)	1
		* WIRE ASSY. LENGTH DETERMINED BY	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	2.9426 PIN, GOVERNOR CONTROL WIRE SWIVEL	
5161464	PIN, SWIVEL	1
120392	WASHER, 1/4" FLAT (12.9190)	1
142583	RETAINER, 13/64" SPRING (12.9640)	1
132105	SCREW #10-32X3/8" FIL HD. (12.9010)	1
	2.9428 CLIP, GOVERNOR CONTROL WIRE TUBE	
5155782	CLIP (7.8320)	1
3290569	CLIP (7.8320)	1
123298	BOLT, 1/4"-28X3/8" (12.9001)	1
120380	LOCKWASHER, 1/4" (12.9200)	1
121902	NUT, 1/4"-28 HEX (12.9120)	1

GROUP NOMENCLATURE

00	ENGINE (less major assemblies)
.1000	Cylinder Block
.1000A	Air Box Drains
.2000	Cylinder Head
.2000A	Engine Lifter Bracket
.3000	Crankshaft, Oil Seals and stabilizers
.3000A	Crankshaft Front Cover
.3000C	Crankshaft Pulley
.3000D	Crankshaft Pulley Belt
.4000A	Flywheel
.5000A	Flywheel Housing
.6000	Connecting Rod and Piston
.7000	Camshaft and Gear Train
.7000A	Balance Weight Cover
.7000B	Accessory Drive
.8000	Valve and Injector Operating Mechanism
.8000A	Rocker Cover

00	**FUEL SYSTEM**
.1000A	**Fuel Injector**
.2000	**Fuel Pump**
.2000A	**Fuel Pump Drain**
.3000A	**Fuel Filter**
.4000	**Fuel Manifold and/or Connections**
.5000A	**Fuel Lines and Fuel Cooler**
.7000A	**Mechanical Governor**
.9000	**Injector Controls**
.9000A	**Throttle Controls**

00	AIR SYSTEM
.3000A	Air Inlet Housing
.4000	Blower
.4000A	Blower Drive Shaft
.4000B	Blower End Plate Cover

00	LUBRICATING SYSTEM
.1000A	Oil Pump
.1000B	Oil Distribution System
.1000C	Oil Pressure Regulator
.2000A	Oil Filter
.2000A	Oil Filter Liner

5.0000	COOLING SYSTEM
5.1000	Fresh Water Pump
5.1000A	Fresh Water Pump Cover
5.2000A	Water Outlet Manifold and/or Elbow
5.2000B	Thermostat
5.2000C	Water By-pass Tube
5.3000B	Water Connections
5.4000A	Fan

6.0000	EXHAUST SYSTEM
6.1000A	Exhaust Manifold
6.2000A	Exhaust Muffler and/or Connections

7.0000	ELECTRICAL—INSTRUMENTS
7.1000A	Battery Charging Generator
7.3000A	Starting Motor

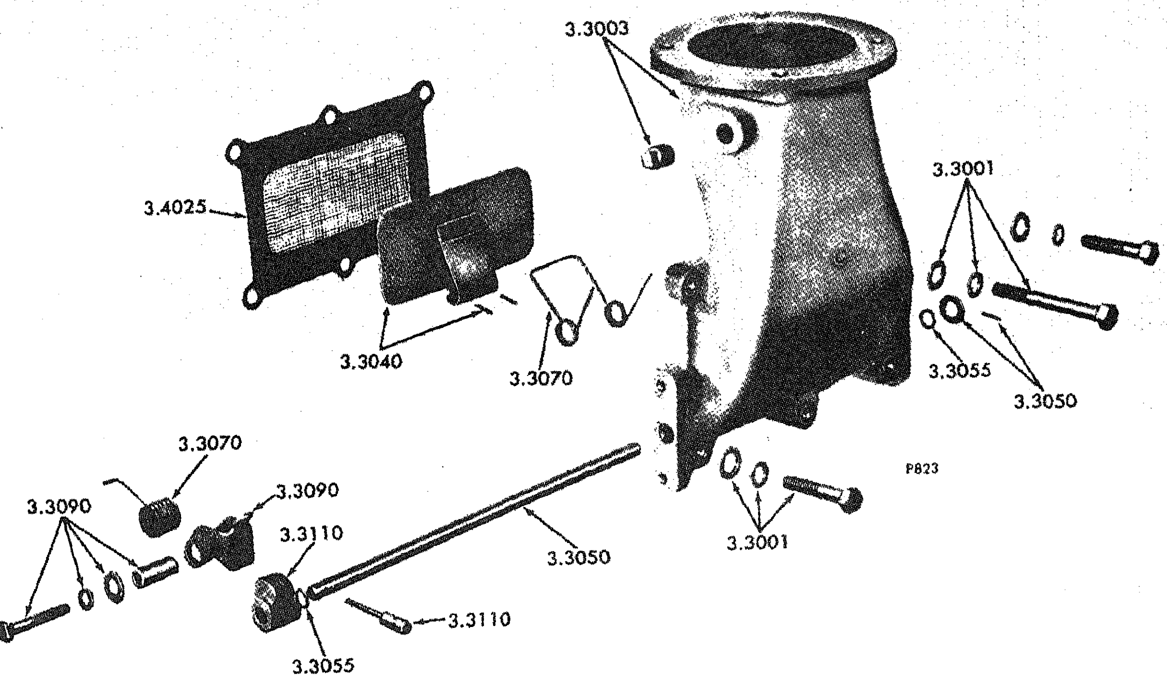
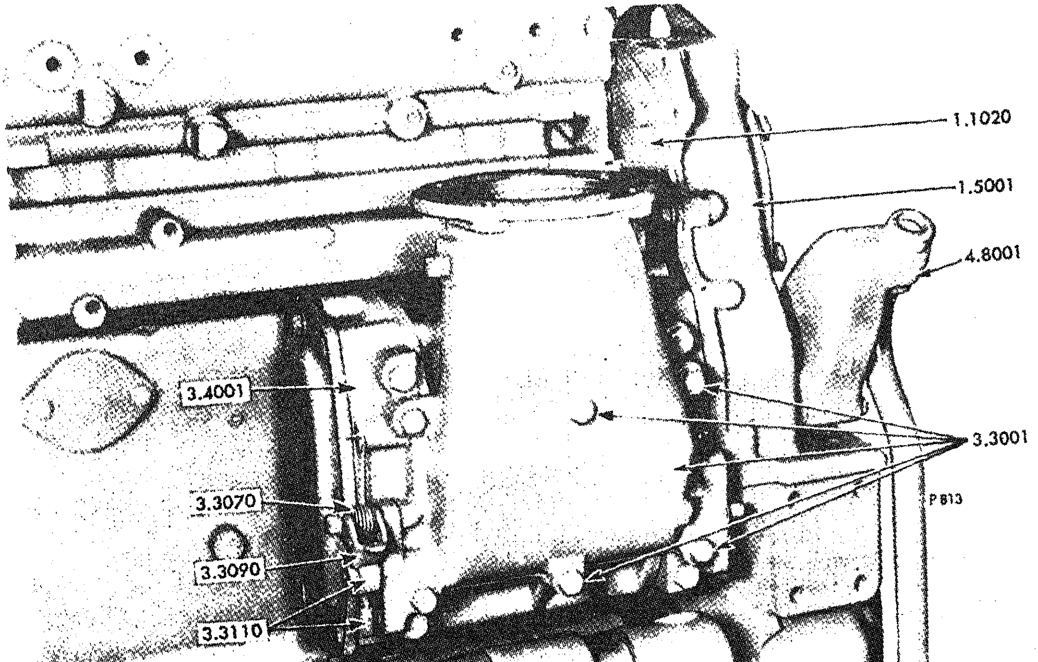


FIG. 3A AIR INLET HOUSING



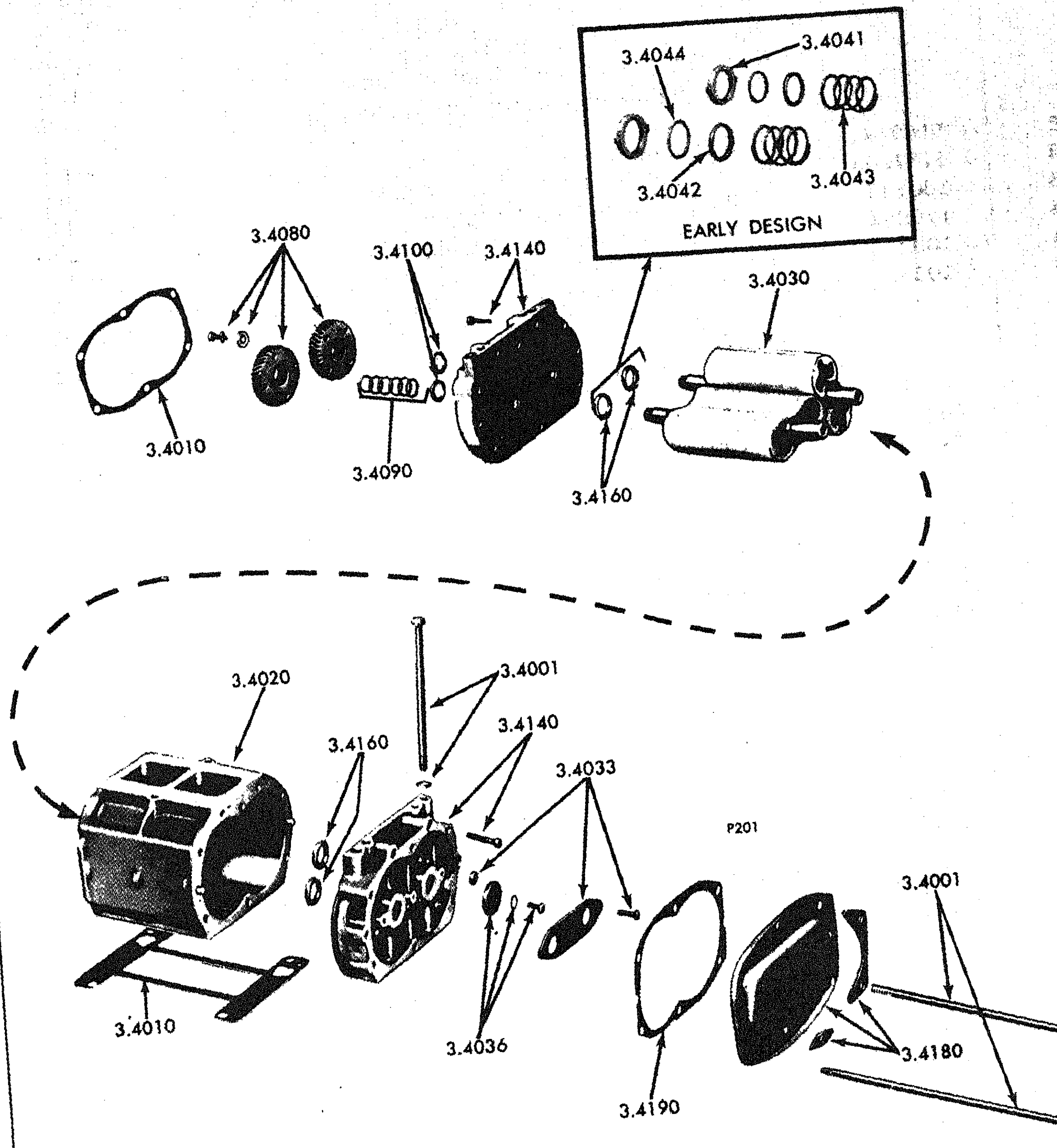


FIG. 4A 3-53 BLOWER

...RT ...BER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	3.3001 HOUSING ASSY., AIR INLET	
	FOR TYPE 478 USE TYPE 407. FOR TYPE 527 USE TYPE 481. A HOUSING ASSY. INCLUDES ITEMS IN 3.003 AND 3.3040 THRU 3.3110	
...40572	HOUSING ASSY.	1
...57244	BOLT, 3/8"-16X1 3/4" (4.4190)	4
...0130	BOLT, 3/8"-16X2" (12.9001)	1
...9851	BOLT, 3/8"-16X3" (12.9001)	1
...3341	WASHER, 3/8" FLAT (12.9190)	6
...3321	LOCKWASHER, 3/8" (12.9200)	6
	3.3003 HOUSING, AIR INLET	
...37406	HOUSING	1
...5010	PLUG, 1/4" PIPE (12.9550)	1
	3.3007 GASKET, AIR INLET HOUSING FLANGE	
...4405	GASKET	1
...6053	GASKET (3.4025) (W/SCREEN)	1
	3.3040 VALVE, AIR INLET HOUSING SHUTDOWN	
...6456	VALVE	1
...436	PIN, 1/8"X11/16" ROLL (12.9300)	2
	3.3050 SHAFT, AIR INLET HOUSING SHUTDOWN VALVE	
	A SHAFT AND CAM ASSY. CONSISTS OF SHAFT, SPACER AND PIN IN 3.3050, PLUS CAM AND LEVER IN 3.3110.	
...3440	SHAFT	1
...341	WASHER, 3/8" FLAT (12.9190)	1
...436	PIN, 1/8"X11/16" ROLL (12.9300)	1
	3.3055 SEAL, AIR INLET HOUSING SHUTDOWN VALVE SHAFT	
[illegible]	SEAL RING	[illegible]

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
3A	5111904	SPRING (VALVE) (INTERNAL)	1
3A,B	5112787	SPRING (LATCH) (R.H. HELIX)	1
		3.3090 LEVER, AIR INLET HOUSING SHUTDOWN VALVE	
3A,B	5114727	LATCH	1
3A	179803	BOLT, 1/4"-20X1 3/4" (12.9001)	1
	120392	WASHER, 1/4" FLAT (12.9190)	1
	120380	LOCKWASHER, 1/4" (12.9200)	1
	5143836	BUSHING, ECCENTRIC	1
		3.3110 LEVER, AIR INLET HOUSING SHUTDOWN RESET	
3A	5122623	CAM	1
3A	5114974	HANDLE ASSY.	1
		3.3250 WIRE, AIR INLET HOUSING SHUTDOWN	
	103319	LOCKWASHER, 1/4"	1
	5146238	* WIRE ASSY. (57"L.) (2.9422)	1
	110730	LOCKWASHER, 3/8" (12.9200)	1
	3796374	GUIDE, WIRE	1
	3290569	CLIP, 3/16" DIA. W/OFFSET	1
	140855	SCREW. #8-32X5/16" L. SET	1
	123298	BOLT, 1/4"-28X3/8"	1
	120393	WASHER, 11/32" FLAT	1
	121902	LOCKWASHER, 1/4"	1
	124925	NUT, 3/8"-24 JAM	1
		* WIRE ASSY. LENGTH DETERMINED BY INSTALLATION. CUT TO SUIT.	
		3.3260 PLATE, AIR INLET HOUSING SHUTDOWN CONTROL	
	5186687	PLATE, INSTRUCTION	1

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
	3.4001 BLOWER ASSY.	
5139305	BLOWER ASSY. (R.H.)	1
5121464	BOLT (10 3/16" L.)	2
5116150	BOLT (10 11/16" L.)	4
5131913	WASHER (7/16") (FLAT)	4
9433110	BOLT, 7/16"-14X6 11/16" (12.9001)	4
	BLOWER ASSY. INCLUDES ITEMS IN 3.4020 AND 3.4030 THRU 3.4040.	
	3.4003 BLOWER KIT, INSTALLATION	
	A KIT INCLUDES ITEMS IN 3.4010, 3.4025, 3.4190, 3.4220, 3.4227 AND COPPER WASHER IN 3.4350.	
	3.4003 BLOWER KIT, INSTALLATION (CONT.)	
5198041	BLOWER INSTALLATION KIT	AR
	3.4005 BLOWER KIT, REPAIR	
	NON-TURBO KIT CONSISTS OF WASHER IN 3.4080, PILOT IN 3.4082, PLUS ITEMS IN 3.4090, 3.4100, 3.4160, 3.4320, AND SPACER IN 3.4370.	
5198684	BLOWER REPAIR KIT (NON-TURBO)	AR
	3.4010 GASKET, BLOWER	
5119433	GASKET (TO END PLATE) (3.4190)	1
5116295	GASKET (TO BLOCK)	1
	3.4020 HOUSING, BLOWER	
5119391	HOUSING, ASSY. (INCLUDES PINS)	1
141242	PIN, 3/8"X7/8" DOWEL (12.9290)	4

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		3.4025 SCREEN, BLOWER	
3A	5196053	SCREEN	1
		3.4030 ROTOR, BLOWER	
		INCLUDES SHAFT AND PIN WHICH ARE NOT SOLD SEPARATELY FOR TYPE 114.	
	5139297	ROTOR ASSY.	2
		3.4033 PLATE, BLOWER ROTOR THRUST	
4A	5116173	PLATE	1
4A	5116170	SPACER	3
4A	9409062	BOLT, 1/4"-20X1" (12.9001)	3
		3.4036 WASHER, BLOWER ROTOR SHAFT THRUST	
4A	5127077	WASHER (25/64" I.D.)	4
4A	9409034	BOLT, 3/8"-24X7/8" (12.9001)	2
		3.4080 GEAR, BLOWER ROTOR	
4A	5119194	GEAR (R.H. HELIX)	1
4A	5119195	GEAR (L.H. HELIX)	1
4A	9409018	BOLT, 5/16"-24X7/8" (12.9001)	2
	5121403	WASHER	2
		3.4090 SHIM, BLOWER ROTOR GEAR	
4A	5116164	SHIM (.002")	AR
4A	5116165	SHIM (.003")	AR
4A	5116166	SHIM (.004")	AR
4A	5116167	SHIM (.005")	AR
		3.4100 SPACER, BLOWER ROTOR GEAR	
4A	5116168	SPACER	2
		3.4140 PLATE, BLOWER HOUSING END	
		A PLATE ASSY. INCLUDES PINS, PLUGS AND STRAINER IN 3.4140 AND SEAL IN 3.4160.	

PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
5134914	PLATE, FRONT	1
5139299	PLATE, REAR	1
5145009	PLUG, 1/8" PIPE (12.9550)	2
117297	SCREW, 5/16"-18X1 3/4" FIL. HD. (12.9010)	4
	3.4160 SEAL, BLOWER HOUSING END PLATE	
5134924	SEAL (LIP TYPE) (NON-TURBO) (STD. I.D.)	4
5199367	# SEAL (USED WITH SLEEVE 5199368) (O.S., I.D.)	AR
	3.4163 SPACER, BLOWER ROTOR SHAFT OIL SEAL	
5199368	# SLEEVE (USED WITH 5199367 SEAL)	AR
	#USED TOGETHER TO RENEW SEALING SURFACE.	
	3.4180 COVER, BLOWER HOUSING END PLATE	
5119429	COVER (FRONT)	1
5119394	PLATE, REINFORCEMENT (LARGE)	2
5119395	PLATE, REINFORCEMENT (SMALL)	2
	3.4190 GASKET, BLOWER HOUSING END PLATE COVER	
5119433	GASKET	1

GROUP NOMENCLATURE

ENGINE (less major assemblies)

Cylinder Block
A Air Box Drains
Cylinder Head
A Engine Lifter Bracket
Crankshaft, Oil Seals and stabilizers
A Crankshaft Front Cover

C Crankshaft Pulley
D Crankshaft Pulley Belt
A Flywheel
A Flywheel Housing

0 Connecting Rod and Piston
0 Camshaft and Gear Train
0A Balance Weight Cover
0B Accessory Drive
0 Valve and Injector Operating Mechanism
0A Rocker Cover

FUEL SYSTEM

0A Fuel Injector
0 Fuel Pump
00A Fuel Pump Drain
00A Fuel Filter
00 Fuel Manifold and/or Connections

00A Fuel Lines and Fuel Cooler

00A Mechanical Governor

00 Injector Controls
00A Throttle Controls

AIR SYSTEM

000A Air Inlet Housing
000 Blower
000A Blower Drive Shaft
000B Blower End Plate Cover

0 LUBRICATING SYSTEM
1000A Oil Pump
1000B Oil Distribution System
1000C Oil Pressure Regulator
2000A Oil Filter

5.0000 COOLING SYSTEM
5.1000 Fresh Water Pump
5.1000A Fresh Water Pump Cover
5.2000A Water Outlet Manifold and/or Elbow
5.2000B Thermostat
5.2000C Water By-pass Tube

5.3000B Water Connections
5.4000A Fan

6.0000 EXHAUST SYSTEM
6.1000A Exhaust Manifold
6.2000A Exhaust Muffler and/or Connections

7.0000 ELECTRICAL—INSTRUMENTS
7.1000A Battery Charging Generator

7.3000A Starting Motor

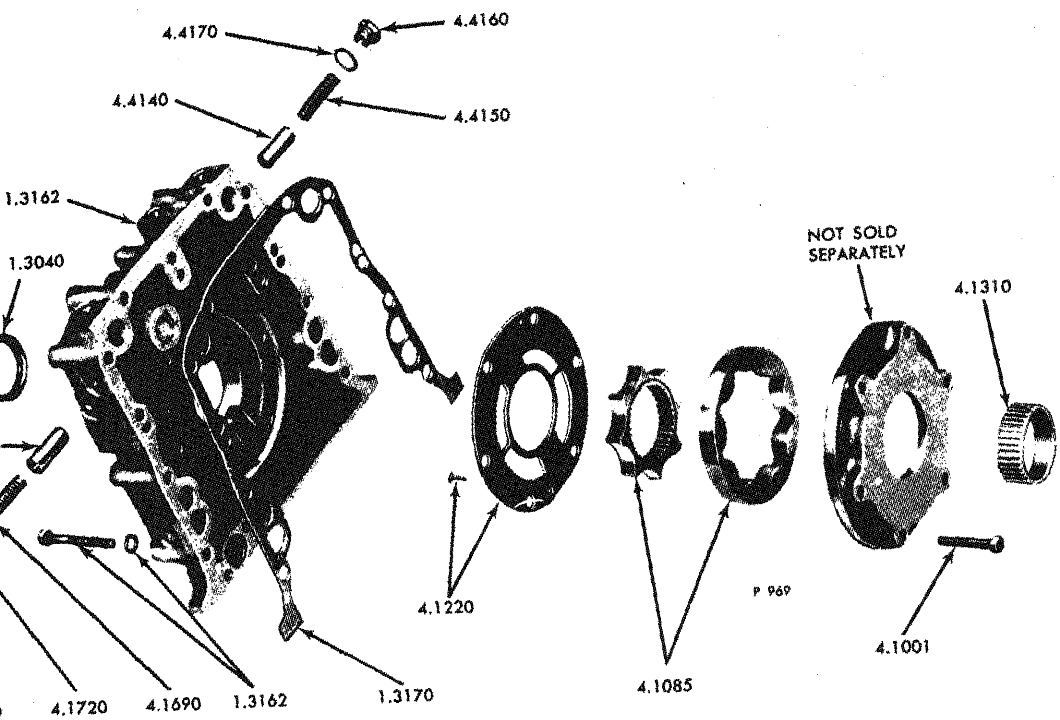


FIG. 1A OIL PUMP AND PRESSURE REGULATOR (Inline Engine)

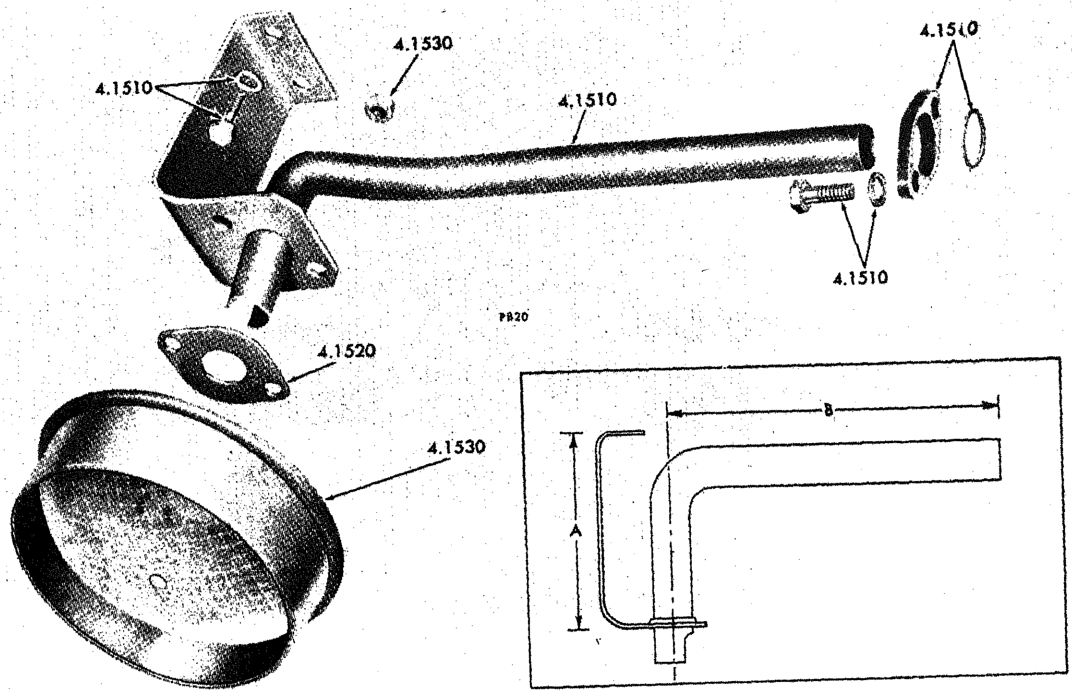


FIG. 2A OIL DISTRIBUTION SYSTEM

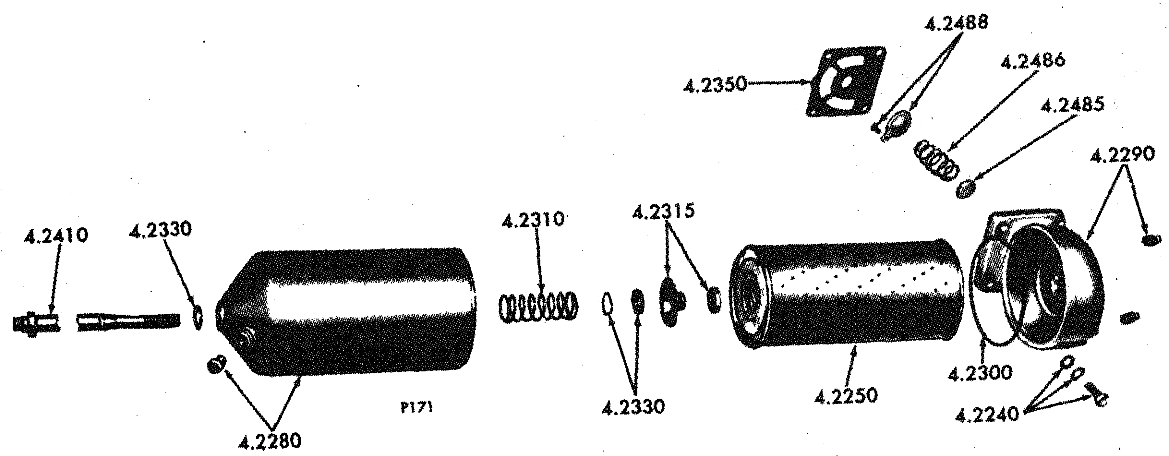
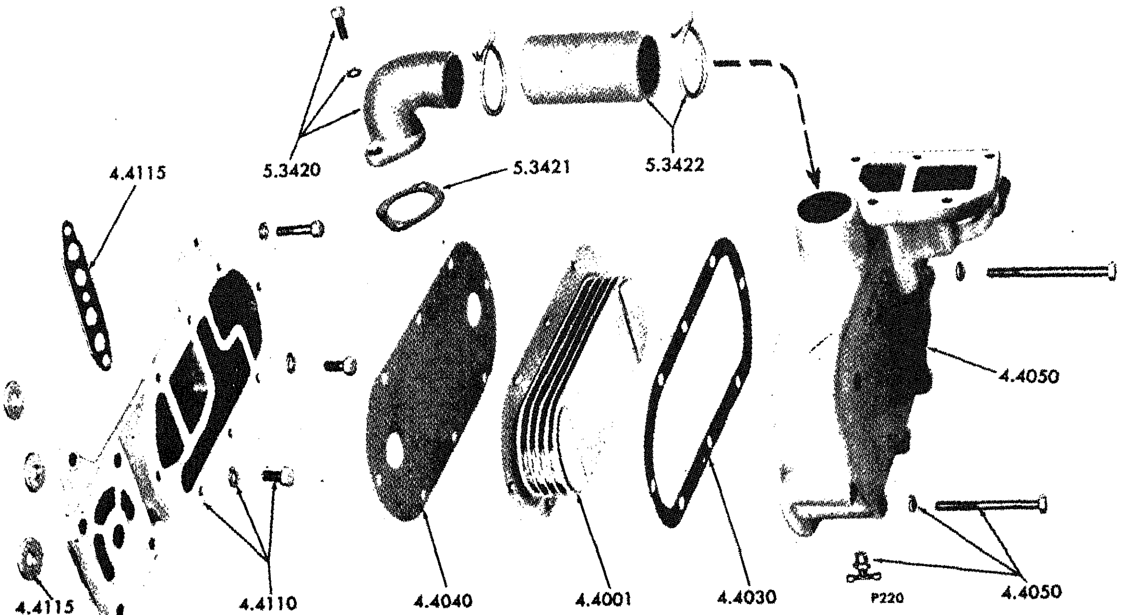
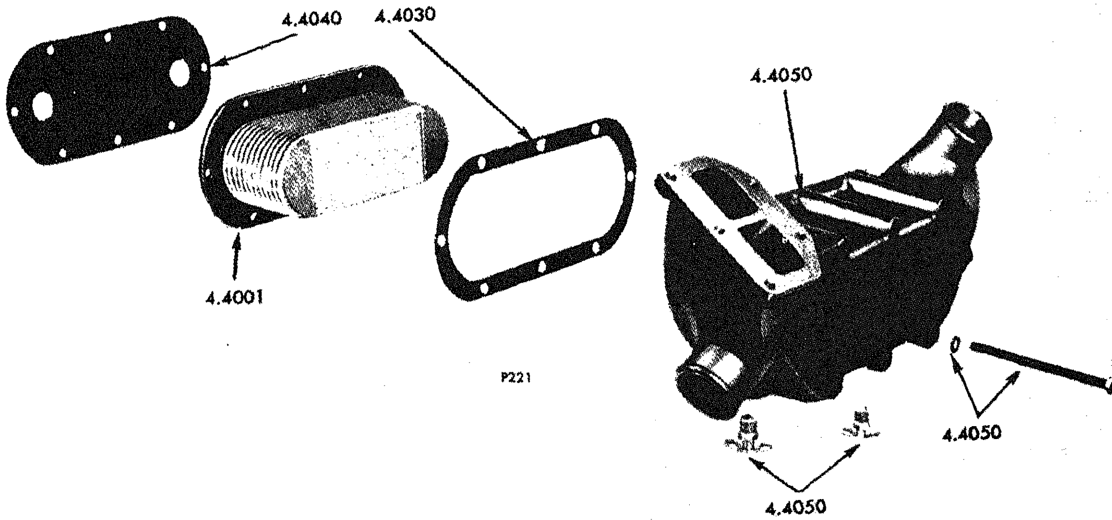


FIG. 3A OIL FILTER




4.4040
4.4030
4.4050
4.4001
P221
4.4050
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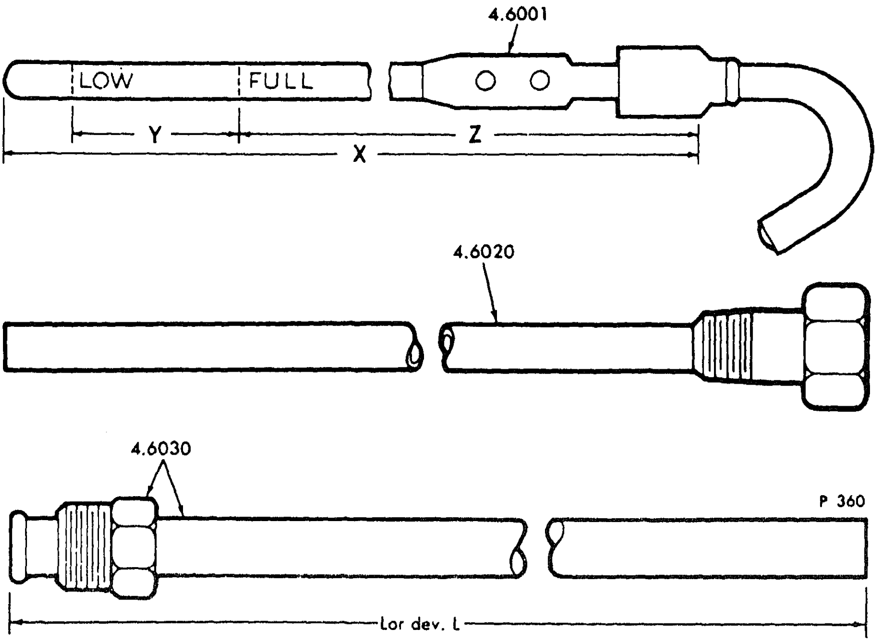
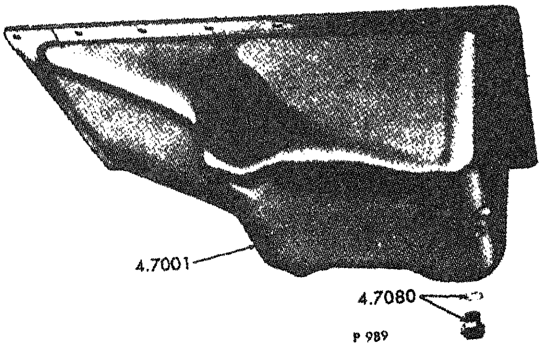


FIG. 6A DIPSTICK



P 989

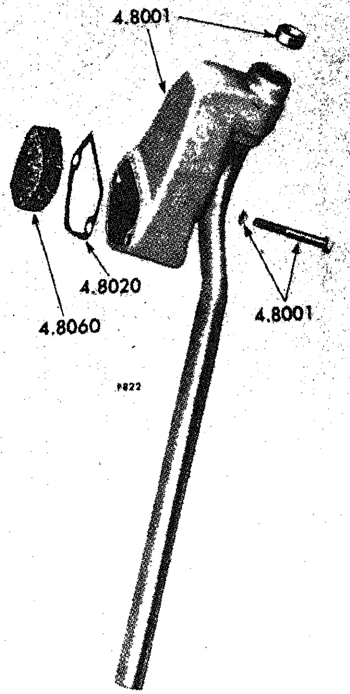


FIG. 8A BREATHER AND OIL FILLER

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTI
		4.1001 PUMP ASSY., OIL	
		INCLUDES ITEMS IN 4.1040 THRU 4.1220 AND 4.1380.	
	5116110	PUMP ASSY.	1
1A	193942	BOLT, 5/16"-18X1 5/8" (AA LOCK) (12.9001)	6
		4.1085 ROTOR ASSY., OIL PUMP	
		INCLUDES INNER AND OUTER ROTORS WHICH ARE NOT SOLD SEPARATELY.	
1A	5195714	ROTOR SET·	1
		4.1220 COVER, OIL PUMP	
1A	5195685	COVER	1
1A	145067	SCREW, #6X3/8" DRIVE (12.9067)	2
		4.1310 GEAR, OIL PUMP DRIVE (ON CRANKSHAFT)	
1A	5144375	GEAR	1
		4.1510 PIPE, OIL PUMP INLET	
2A	5126211	* PIPE (A-5.12", B14")	1
2A	5119425	FLANGE	1
2A	5127175	SEAL RING	1
2A	179816	BOLT, 5/16"-18X3/4" (12.9001)	4
	103340	WASHER, 5/16" FLAT (12.9190)	2
2A	103320	LOCKWASHER, 5/16" (12.9200)	AR
		*INCLUDES SUPPORT 5125947 NOT SERVICED SEPERATELY.	
		4.1530 SCREEN, OIL PUMP INLET	
2A	5126456	SCREEN ASSY.	1
	5152385	SCREEN	1
2A	274558	NUT, 5/16"-24 HEX.LOCK (12.9140)	2
		4.1690 SPRING, OIL PRESSURE REGULATOR	
1A	5126436	SPRING (ORANGE STRIPE) (4.1260)	2

FIG	PART NUMBER	GROUP NUMBER , NAME AND DESCRIPTION	QUAN
		4.1700 VALVE, OIL PRESSURE REGULATOR	
1A	5177777	VALVE (4.4140)	
		4.1710 PLUG, OIL PRESSURE REGULATOR	
1A	5113657	PLUG	
		4.1720 GASKET, OIL PRESSURE REGULATOR PLUG	
1A	5177773	GASKET (4.4170)	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTIT
		4.2240 FILTER ASSY., OIL	
		SEE ASSEMBLY BREAKDOWN AS INDICATED BELOW. FOR TYPES 130 & 134 ALSO SEE OIL FILTER LINES, 4.3000A, TYPE 98. FOR TYPE 139 USE TYPE 147.	
	5125025	FILTER ASSY.	1
	5575213	DECAL (4.2280)	1
	128003	BUSHING, 1"X3/4" RED. (12.9570)	AR
	5111798	PLUG, 1" PIPE (12.9550)	AR
		A 4.2240 FILTER ASSY., OIL	
	5125025	FILTER ASSY.	1
		4.2250 ELEMENT, OIL FILTER	
3A	5574978	ELEMENT (6") (AC TYPE PF-147)	1
		4.2280 SHELL, OIL FILTER	
3A	5574906	SHELL (INCLUDES PLUG)	1
3A	5570480	PLUG (2.3050)	1
		4.2290 COVER, OIL FILTER (ADAPTOR)	
	5147684	ADAPTOR	1
		4.2300 GASKET, OIL FILTER COVER	
3A	5571024	GASKET	1
		4.2310 SPRING, OIL FILTER	
3A	5187308	SPRING	1
		4.2315 RETAINER, OIL FILTER SPRING	
3A	5187309	RETAINER	1
	122366	NUT, 5/8"-18 HEX. (12.9120)	1

IG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		4.2330 GASKET, OIL FILTER COVER NUT	
A	5187310	GASKET, RETAINER	1
A	6437298	GASKET	1
	5154538	WASHER (1.8182)	1
		4.2410 STUD, OIL FILTER CENTER	
A	5116427	STUD	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANT
		4.3025 ADAPTOR, OIL FILTER TUBE (TO OIL COOLER ADAPTOR)	
	5134303	ADAPTOR (AT BLOCK)	1
10A	186622	BOLT, 3/8"-16X1 1/4" (12.9001)	4
	103321	LOCKWASHER, 3/8" (12.9200)	4
		4.3027 GASKET, OIL FILTER TUBE ADAPTOR	
	5121205	GASKET (4.2350)	1
		4.3055 VALVE, OIL FILTER TUBE ADAPTOR BY-PASS	
	5133431	# VALVE # PART OF VALVE KIT 5198303 (4.2485)	1
		4.3057 SPRING, OIL FILTER TUBE ADAPTOR BY-PASS VALVE	
	5134477	# SPRING (4.2486) # PART OF 5198303 VALVE KIT (4.2485)	1
		4.3060 RETAINER, OIL FILTER TUBE ADAPTOR BY-PASS SPRING	
	5134456	# RETAINER (4.2488)	1
	160221	# SCREW #12-24X1/2" (12.9065) # PART OF 5198303 VALVE KIT (4.2485)	1

	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		4.4001 CORE ASSY., OIL COOLER	
	8501328	CORE ASSY. (6 PLATE)	1
		4.4030 GASKET, OIL COOLER CORE INNER	
C	5150155	GASKET	1
		4.4040 GASKET, OIL COOLER CORE OUTER	
C	5154215	GASKET	1
		4.4050 HOUSING, OIL COOLER	
	5119452	HOUSING	1
	103647	DRAINCOCK, 1/4" (12.9510)	1
	179830	BOLT, 5/16"-18X3" (12.9001)	7
	186270	BOLT, 5/16"-18X3 1/2" (12.9001)	1
	103320	LOCKWASHER, 5/16" (12.9200)	8
		4.4110 ADAPTOR, OIL COOLER	
	5123414	ADAPTOR	1
	186622	BOLT, 3/8"-16X1 1/4" (12.9001)	4
	179847	BOLT, 3/8"-16X2" (12.9001)	2
	103321	LOCKWASHER, 3/8" (12.9200)	AR
		4.4115 GASKET, OIL COOLER ADAPTOR TO BLOCK	
	5152904	GASKET	3
	5119286	GASKET	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QU
		4.5010 CAP, OIL FILLER TUBE	
*	5108474	CAP ASSY. (TWIST) * FIG. 9D OF 1.0000.	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		4.6001 DIPSTICK	
5A	5109253	+ DIPSTICK (X-12", Y-94", Z-10.54"). + NOT SERVICED: USE 5146680.	1
		4.6020 GUIDE, DIPSTICK	
5A	5121062	GUIDE (1 1/8" L.)	1
		4.6030 ADAPTOR, DISTICK	
	5121061	* ADAPTOR (8.50" L.)	1
	137401	NUT, 1/2" INV. FL. TUBE (12.9500)	1
		*NOT SERVICED: USE 5109621	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QU
		4.7001 PAN, OIL	
	5146360	PAN (STAMPED)	
7B	5148437	BOLT, 5/16"-18X1" (W/LW) (12.9001)	
		4.7030 GASKET, OIL PAN TO BLOCK	
7B	5116256	GASKET	
		4.7080 PLUG, OIL PAN DRAIN	
		PLUGS ARE OPTIONAL WHEN MULTIPLE QUANTITIES ARE SHOWN IN SAME TYPE.	
	144014	PLUG, 1/2" SQ.HD. (12.9550)	
	5145013	PLUG, 3/4" PIPE HEX. SKT. (12.9550)	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		4.8001 PIPE, BREATHER	
		A PIPE ASSY. (PLAIN) INCLUDES PLUG IN 4.8001 AND FILTER IN 4.8060. A PIPE ASSY. (WITH OIL FILLER) INCLUDES FILLER CAP CHAIN IN 4.5030.	
8A	5116395	PIPE ASSY. (PLAIN)	1
8A	5150829	PLUG, 7/8" CUP	1
8A	179828	BOLT, 5/16"-18X2 1/2" (12.9001)	2
8A	103320	LOCKWASHER, 5/16" (12.9200)	2
		4.8020 GASKET, BREATHER TUBE	
8A	5116391	GASKET (1.5060)	1
		4.8060 FILTER UNIT, BREATHER OIL SEPARATOR	
8A	5163918	FILTER	1

GROUP NOMENCLATURE

1.0000 ENGINE (less major assemblies)
- 1.1000 Cylinder Block
- 1.1000A Air Box Drains
- 1.2000 Cylinder Head
- 1.2000A Engine Lifter Bracket
- 1.3000 Crankshaft, Oil Seals and stabilizers
- 1.3000A Crankshaft Front Cover
- 1.3000C Crankshaft Pulley
- 1.3000D Crankshaft-Pulley Belt
- 1.4000A Flywheel
- 1.5000A Flywheel Housing
- 1.6000 Connecting Rod and Piston
- 1.7000 Camshaft and Gear Train
- 1.7000A Balance Weight Cover
- 1.7000B Accessory Drive
- 1.8000 Valve and Injector Operating Mechanism
- 1.8000A Rocker Cover

2.0000 FUEL SYSTEM
- 2.1000A Fuel Injector
- 2.2000 Fuel Pump
- 2.2000A Fuel Pump Drain
- 2.3000A Fuel Filter
- 2.4000 Fuel Manifold and/or Connections
- 2.5000A Fuel Lines and Fuel Cooler
- 2.7000A Mechanical Governor
- 2.9000 Injector Controls
- 2.9000A Throttle Controls

3.0000 AIR SYSTEM
- 3.3000A Air Inlet Housing
- 3.4000 Blower
- 3.4000A Blower Drive Shaft
- 3.4000B Blower End Plate Cover

4.0000 LUBRICATING SYSTEM
- 4.1000A Oil Pump
- 4.1000B Oil Distribution System
- 4.1000C Oil Pressure Regulator
- 4.2000A Oil Filter
- 4.3000A Oil Filter Lines
- 4.4000A Oil Cooler
- 4.5000A Oil Filler
- 4.6000A Dipstick
- 4.7000A Oil Pan

5.0000 COOLING SYSTEM
- **5.1000 Fresh Water Pump**
- **5.1000A Fresh Water Pump Cover**
- **5.2000A Water Outlet Manifold and/or Ell**
- **5.2000B Thermostat**
- **5.2000C Water By-pass Tube**
- **5.3000B Water Connections**
- **5.4000A Fan**

6.0000 EXHAUST SYSTEM
- 6.1000A Exhaust Manifold
- 6.2000A Exhaust Muffler and/or Connecti

7.0000 ELECTRICAL—INSTRUMENTS
- 7.1000A Battery Charging Generator
- 7.3000A Starting Motor

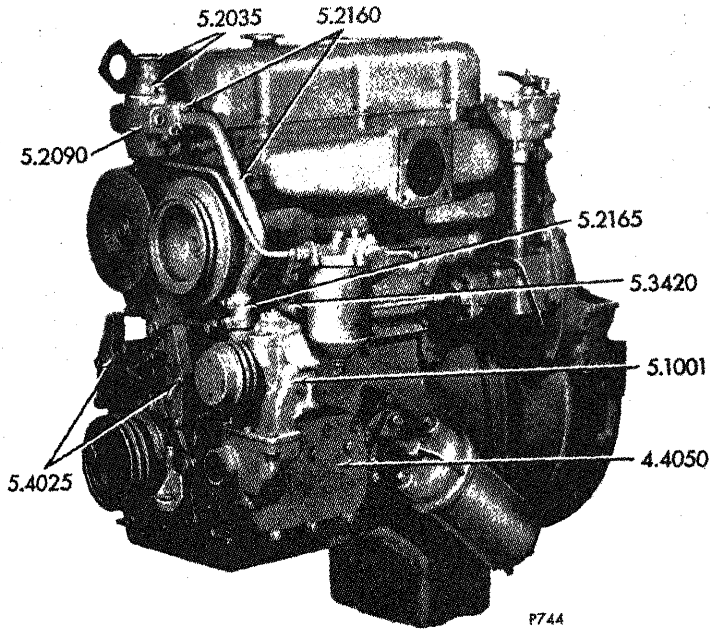


FIG. 1A TYPICAL COOLING SYSTEM (Inline Engines)

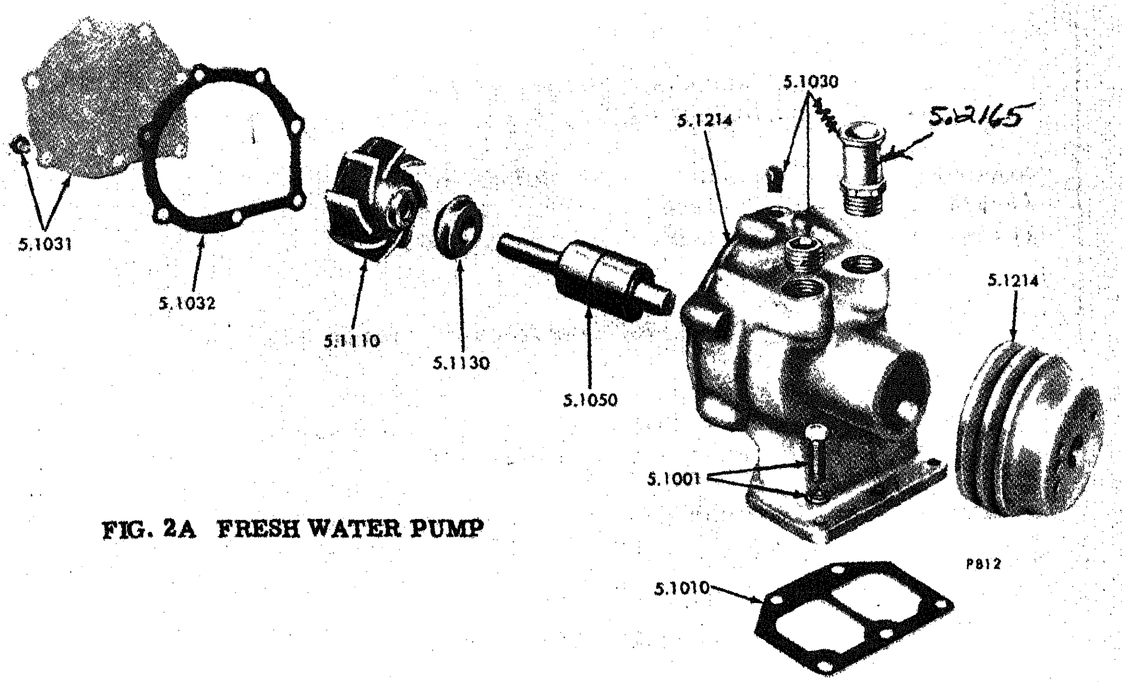


FIG. 2A FRESH WATER PUMP

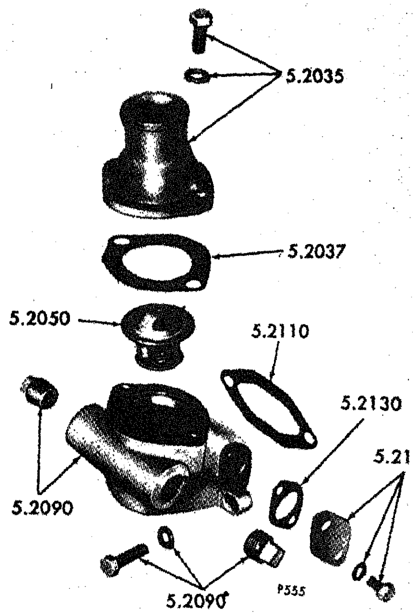


FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QU
		5.1001 PUMP ASSY., FRESH WATER	
		SEE ASSEMBLY BREAKDOWN AS INDICATED BELOW.	
1A	5144686	PUMP ASSY. (R.H. ROTATION)	
	186625	BOLT, 5/16"-18X7/8" (12.9001)	
	103320	LOCKWASHER, 5/16" (12.9200)	
		5.1002 RECONDITIONING KIT, FRESH WATER PUMP	
		INCLUDES ITEMS IN 5.1010, 5.1032, 5.1050, 5.1110, AND 5.1130	
	5199534	RECONDITIONING KIT (R.H. ROTATION PUMP)	
		5.1010 GASKET, FRESH WATER PUMP	
2A	5133107	GASKET	
		5.1115 REPLACEMENT KIT, FRESH WATER PUMP SEAL SEAT	
		A REPLACEMENT KIT INCLUDES CERAMIC INSERT AND ADHESIVE.	
	5197279	REPLACEMENT KIT, IMPELLER INSERT	
		A 5.1001 PUMP ASSY., FRESH WATER	
	5144686	PUMP ASSY. (R.H. ROTATION)	
		5.1030 BODY, FRESH WATER PUMP	
2A	5144689	BODY	
	5145009	PLUG, 1/8" PIPE (12.9550)	
		5.1031 COVER, FRESH WATER PUMP	
2A	5119283	COVER	
	5148436	BOLT, 5/16"-18X3/4" (W/LW) (12.9001)	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		5.1032 GASKET, FRESH WATER PUMP BODY COVER	
2A	5119282	GASKET	1
		5.1050 SHAFT, FRESH WATER PUMP	
2A	904827	SHAFT ASSY. (INCLUDES BEARING)	1
		5.1110 IMPELLER, FRESH WATER PUMP	
2A	5146354	IMPELLER (WITH CERAMIC INSERT)	1
		5.1130 SEAL, FRESH WATER PUMP	
2A	5130959	SEAL	1
		5.1214 PULLEY, FRESH WATER PUMP	
2A	5144503	PULLEY	1

IG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		5.2035 ELBOW, WATER OUTLET	
A	5134777	ELBOW, 90 DEG.	1
	186619	BOLT, 3/8"-16X1 1/8" (12.9001)	1
	179850	BOLT, 3/8"-16X2 3/4" (12.9001)	1
	103321	LOCKWASHER,3/8" (12.9200)	2
		5.2037 GASKET, WATER OUTLET ELBOW	
	5116092	GASKET	1
		5.2050 THERMOSTAT ASSY.	
A,B	3146695	THERMOSTAT ASSY. (170 DEG. OPENING TEMP.)	1
		5.2090 HOUSING, THERMOSTAT	
A	5123247	HOUSING	1
	5145014	PLUG, 3/8" PIPE (12.9550)	2
	5115214	PLUG, 1/2" PIPE (12.9550)	2
	108608	BOLT, 3/8"-16X 2 1/8" (12.9001)	2
	103321	LOCKWASHER, 3/8" (12.9200)	2
		5.2110 GASKET, THERMOSTAT HOUSING	
B	5116242	GASKET (TO CYLINDER HEAD) (1.2044)	1
		5.2120 COVER, THERMOSTAT HOUSING	
	5119426	FLANGE	1
	186618	BOLT, 5/16"-18X5/8" (129001)	2
	103320	LOCKWASHER, 5/16" (12.9200)	2
		5.2130 GASKET, THERMOSTAT HOUSING COVER	
B	5128139	GASKET	1
		5.2160 TUBE, WATER BY-PASS	
A	5108944	TUBE	1
A	5119425	FLANGE (4.1510)	1
	5184301	SEAL RING (4.4060)	1
	5142549	PLUG, 3/4" PIPE (12.9550)	1
	186625	BOLT, 5/16"-18X7/8" (12.9001)	2
	103320	LOCKWASHER, 5/16" (12.9200)	2

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		5.2165 HOSE, WATER BY-PASS TUBE	
1A	5119251	# HOSE (7/8" I.D. X1.74" L.) (5169721)	1
1A	5186840	CLAMP, 1" DIA. HOSE (12.9660)	2
2A	5144702	CONNECTOR, 3/4" PIPE .88 HOSE	1
		# NOT SERVICED: USE PART NUMBER IN PARENTHESES AND CUT LENGTH TO 1.74"	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QU
		5.3420 ELBOW, OIL COOLER WATER OUTLET	
1A	5121184	* ELBOW	
@	179819	BOLT, 5/16"-18X1 1/8" (12.9001)	
@	103320	LOCKWASHER, 5/16" (12.9200)	
		@FIG. 4A of 4.0000.	
		* NOT SERVICED: USE 5138275 PLUS	
		(2) 5145014 PLUGS.	
		5.3421 GASKET, OIL COOLER WATER OUTLET ELBOW	
@	5116357	GASKET (1.1070)	
		@FIG. 4A of 4.0000.	
		5.3422 HOSE, OIL COOLER WATER OUTLET ELBOW	
@	5116093	# HOSE (1 7/8" I.D. X4 3/4") (5199777)	
	5186841	CLAMP, 1 9/16"-2 1/2" DIA. HOSE (12.9660)	
		@FIG 4A of 4.0000.	
		#NOT SERVICED: USE PART NUMBER IN PARENTHESES AND CUT LENGTH TO 4 3/4"	

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		5.4010 BLADE, FAN	
	5147710	BLADE (18"-6 BLADE, BLOWER)	1
	186629	BOLT, 5/16"-18X1" (12.9001)	6
	103320	LOCKWASHER, 5/16" (12.9200)	6
		5.4015 PULLEY & HUB ASSY., FAN	
		SEE ASSEMBLY BREAKDOWN AS INDICATED BELOW.	
	5145535	PULLEY ASSY.	1
		5.4025 SUPPORT, FAN MOUNTING	
1A	5108945	SUPPORT	2
	5164294	SPACER (13/32"X7/8"X1/8") (7.1581)	4
	186612	BOLT, 3/8"-16X1 3/8" (12.9001)	4
	272429	BOLT, 3/8"-16X4 1/8" (12.9001)	4
	103321	LOCKWASHER, 3/8" (12.9200)	8
		B 5.4015 PULLEY AND HUB ASSY. (FAN)	
	5145535	PULLEY ASSY.	1
		5.4090 BRACKET, FAN SHAFT	
	5145389	BRACKET (INCLUDES INTEGRAL SHAFT)	1
		5.4110 BEARING, FAN SHAFT	
	7450630	BEARING	1
	7451080	BEARING	1
	5131095	RETAINER, GREASE	1
	5131124	SHIM (.15)	AR
	5131205	SHIM (.20)	AR
	5131206	SHIM (.25)	AR
		5.4140 RETAINER, FAN SHAFT BEARING	
	5131122	SPACER, BEARING (5.4170)	1
	5134025	WASHER, 33/64"X1 1/2"X.32" CHAMF.	1
	9409060	BOLT, 1/2"-20X1 1/2" LOCK (12.9001)	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QU
		5.4150 SEAL, FAN SHAFT	
	5100408	SEAL	
		5.4180 CAP AND SPACER, FAN HUB	
	5144798	CAP (PULLEY)	
		5.4235 PULLEY, FAN	
	5145376	PULLEY (4.30" DIA., 2 GROOVE)	

GROUP NOMENCLATURE

1.0000	ENGINE (less major assemblies)
1.1000	Cylinder Block
1.1000A	Air Box Drains
1.2000	Cylinder Head
1.2000A	Engine Lifter Bracket
1.3000	Crankshaft, Oil Seals and stabilizers
1.3000A	Crankshaft Front Cover
1.3000C	Crankshaft Pulley
1.3000D	Crankshaft Pulley Belt
1.4000A	Flywheel
1.5000A	Flywheel Housing
1.6000	Connecting Rod and Piston
1.7000	Camshaft and Gear Train
1.7000A	Balance Weight Cover
1.7000B	Accessory Drive
1.8000	Valve and Injector Operating Mechanism
1.8000A	Rocker Cover

2.0000	FUEL SYSTEM
2.1000A	Fuel Injector
2.2000	Fuel Pump
2.2000A	Fuel Pump Drain
2.3000A	Fuel Filter
2.4000	Fuel Manifold and/or Connections
2.5000A	Fuel Lines and Fuel Cooler
2.7000A	Mechanical Governor
2.9000	Injector Controls
2.9000A	Throttle Controls

3.0000	AIR SYSTEM
3.3000A	Air Inlet Housing
3.4000	Blower
3.4000A	Blower Drive Shaft
3.4000B	Blower End Plate Cover

4.0000	LUBRICATING SYSTEM
4.1000A	Oil Pump
4.1000B	Oil Distribution System
4.1000C	Oil Pressure Regulator
4.2000A	Oil Filter
4.3000A	Oil Filter Lines

5.0000	COOLING SYSTEM
5.1000	Fresh Water Pump
5.1000A	Fresh Water Pump Cover
5.2000A	Water Outlet Manifold and/o
5.2000B	Thermostat
5.2000C	Water By-pass Tube
5.3000B	Water Connections
5.4000A	Fan

6.0000	**EXHAUST SYSTEM**
6.1000A	**Exhaust Manifold**
6.2000A	**Exhaust Muffler and/or Conn**

7.0000	ELECTRICAL—INSTRUMENTS
7.1000A	Battery Charging Generator
7.3000A	Starting Motor

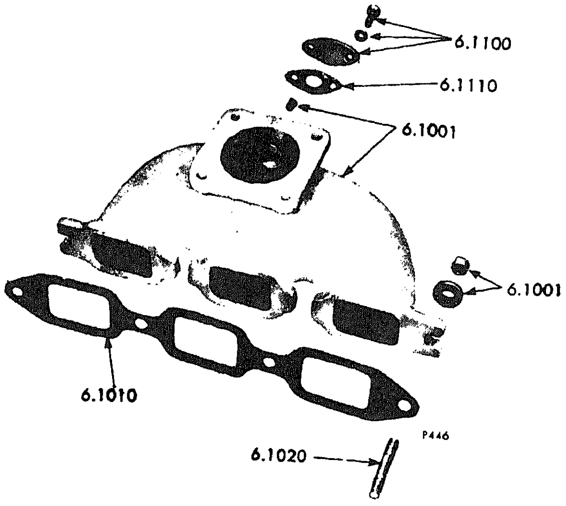


FIG. 1A EXHAUST MANIFOLD (Center Outlet)

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTITY
		6.1001 MANIFOLD, EXHAUST	
1A	5130330	* MANIFOLD	AR
1A	113175	* PLUG, 1/8" PIPE (12.9550)	AR
1A	5188273	WASHER (DISHED, 1 1/4" O.D.)	4
1A	127855	NUT, 7/16"-20 HEX BR. (12.9120)	4
		* FOR A THREE USE A QUANTITY OF "1"	
		6.1010 GASKET, EXHAUST MANIFOLD	
1A	5116205	* GASKET	AR
		* USE A QUANTITY OF "1" FOR A-THREE	
		6.1020 STUD, EXHAUST MANIFOLD TO HEAD	
1A	5112899	STUD, 7/16"X2 3/32" L.	AR

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANT
		6.2085 FLANGE, EXHAUST	
	NPN	FLANGE (CUSTOMER FURNISHED)	1
		6.2105 GASKET, EXHAUST OUTLET	
	5108377	GASKET	1

GROUP NOMENCLATURE

1.0000	ENGINE (less major assemblies)
1.1000	Cylinder Block
1.1000A	Air Box Drains
1.2000	Cylinder Head
1.2000A	Engine Lifter Bracket
1.3000	Crankshaft, Oil Seals and stabilizers
1.3000A	Crankshaft Front Cover
1.3000C	Crankshaft Pulley
1.3000D	Crankshaft Pulley Belt
1.4000A	Flywheel
1.5000A	Flywheel Housing
1.6000	Connecting Rod and Piston
1.7000	Camshaft and Gear Train
1.7000A	Balance Weight Cover
1.7000B	Accessory Drive
1.8000	Valve and Injector Operating Mechanism
1.8000A	Rocker Cover
2.0000	FUEL SYSTEM
2.1000A	Fuel Injector
2.2000	Fuel Pump
2.2000A	Fuel Pump Drain
2.3000A	Fuel Filter
2.4000	Fuel Manifold and/or Connections
2.5000A	Fuel Lines and Fuel Cooler
2.7000A	Mechanical Governor
2.9000	Injector Controls
2.9000A	Throttle Controls
3.0000	AIR SYSTEM
3.3000A	Air Inlet Housing
3.4000	Blower
3.4000A	Blower Drive Shaft
3.4000B	Blower End Plate Cover
.0000	LUBRICATING SYSTEM
4.1000A	Oil Pump
4.1000B	Oil Distribution System
4.1000C	Oil Pressure Regulator
4.2000A	Oil Filter
4.3000A	Oil Filter Lines
4.4000A	Oil Cooler
4.5000A	Oil Filler
4.6000A	Dipstick
5.0000	COOLING SYSTEM
5.1000	Fresh Water Pump
5.1000A	Fresh Water Pump Cover
5.2000A	Water Outlet Manifold and/or Elb
5.2000B	Thermostat
5.2000C	Water By-pass Tube
5.3000B	Water Connections
5.4000A	Fan
6.0000	EXHAUST SYSTEM
6.1000A	Exhaust Manifold
6.2000A	Exhaust Muffler and/or Connection
7.0000	**ELECTRICAL—INSTRUMENTS**
7.1000A	**Battery Charging Generator**
7.3000A	**Starting Motor**

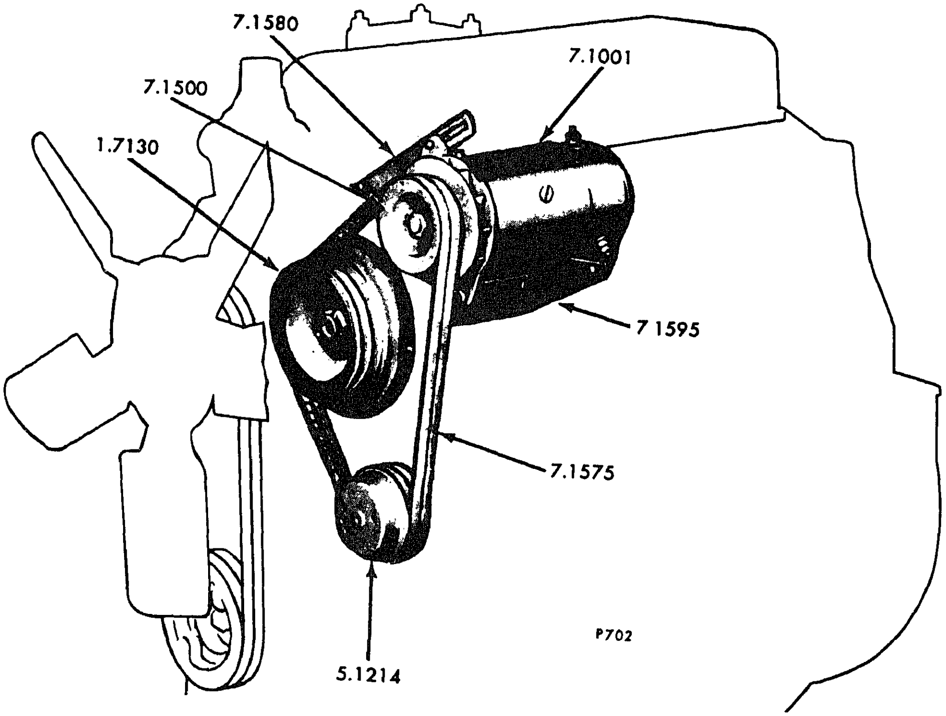


FIG. 1A BATTERY CHARGING GENERATOR

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANTIT
		7.1001 GENERATOR ASSY.	
		NOTE: SERVICE ON ELECTRICAL EQUIPMENT IN THIS SECTION SO INDICATED (*) IS HANDLED THRU UNITED DELCO.	
1A	1100583	* ALTERNATOR (12V., 42 AMP., C.W./ C.C.W., NEGATIVE GROUND)	1
	186285	BOLT, 3/8"-16X4" (12.9001)	1
	5131433	WASHER, SPECIAL (1.5001)	2
	103321	LOCKWASHER, 3/8" (12.9200)	1
	117062	NUT, 3/8"-16 (12.9120)	1
		7.1005 SHIELD, GENERATOR	
	5148599	SHIELD, HEAT (L.H.)	1
	5131201	BRACKET	1
	179816	BOLT, 5/16"-18X3/4" (12.9001)	1
	103340	WASHER, 5/16" FLAT (12.9190)	2
	103320	LOCKWASHER, 5/16" (12.9200)	1
	102634	NUT, 5/16"-18	1
		7.1440 FAN, GENERATOR	
	1959703	* FAN (INCLUDES BAFFLE)	1
		7.1500 PULLEY, GENERATOR	
1A	5132527	PULLEY	1
		7.1575 BELT, GENERATOR DRIVE	
1A	5133172	BELT SET (2 BELTS, 43"L.X.380"W.)	1
		7.1580 STRAP, GENERATOR ADJUSTING	
1A	5148774	STRAP	1
	5121403	SPACER, 3/16" THICK (3.4080)	1
	179819	BOLT, 5/16"-18X1 1/8" (12.9001)	1
	186612	BOLT, 3/8"-16X1 1/4" (12.9001)	1
	103341	WASHER, 3/8" FLAT (12.9190)	1
	103320	LOCKWASHER, 5/16" (12.9200)	1
	103321	LOCKWASHER, 3/8" (12.9200)	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION	QUANT[I]
		7.1595 BRACKET, GENERATOR MOUNTING	
1A	5148790	BRACKET (L.H.)	1
	5139747	BUSHING	1
	5148840	SPACER, 1.06" THICK	1
	9414215	BOLT, 3/8"-16X2 1/2" (12.9001)	3
		7.1630 WIRE ASSY., GENERATOR TO REGULATOR	
	5100420	WRIE ASSY. (INCLUDES RECTIFIER)	1
	106498	LOCKWASHER, #12	1
	103089	NUT, 12-24 HEX.	1

FIG	PART NUMBER	GROUP NUMBER, NAME AND DESCRIPTION
		7.3001 MOTOR ASSY., STARTING
		FOR TYPE 141 USE TYPE 210. NOTE: SERVICE ON ELECTRICAL EQUIPMENT IN THIS SECTION SO INDICATED (*) IS HANDLED THROUGH UNITED DELCO.
	1113237	* MOTOR ASSY. (12V., C.W., GRD. SPRAG)
	9418228	BOLT, 5/8-11X1 3/4", 12 PT (12.9005)
	223435	BOLT, 5/8"-11X1 3/4" (12.9001)
	103325	LOCKWASHER, 5/8" (12.9200)

y Order of the Secretary of the Army:

E. C. MEYER
General, United States 'A
Chief of Staff

fficial:

J. C. PENNINGTON
Major General, United States Army
The Adjutant General

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THE METRIC SYSTEM AND EQUIVALENTS

LINEAR MEASURE

1 Centimeter = 10 Millimeters = 0.01 Meters = 0.3937 Inches
1 Meter = 100 Centimeters = 1000 Millimeters = 39.37 Inches
1 Kilometer = 1000 Meters = 0.621 Miles

WEIGHTS

1 Gram = 0.001 Kilograms = 1000 Milligrams = 0.035 Ounces
1 Kilogram = 1000 Grams = 2.2 Lb
1 Metric Ton = 1000 Kilograms = 1 Megagram = 1.1 Short Tons

LIQUID MEASURE

1 Milliliter = 0.001 Liters = 0.0338 Fluid Ounces
1 Liter = 1000 Milliliters = 33.82 Fluid Ounces

SQUARE MEASURE

1 Sq Centimeter = 100 Sq Millimeters = 0.155 Sq Inches
1 Sq Meter = 10,000 Sq Centimeters = 10.76 Sq Feet
1 Sq Kilometer = 1,000,000 Sq Meters = 0.386 Sq Miles

CUBIC MEASURE

1 Cu Centimeter = 1000 Cu Millimeters = 0.06 Cu Inches
1 Cu Meter = 1,000,000 Cu Centimeters = 35.31 Cu Feet

TEMPERATURE

$5/9\,(^{0}F - 32) = {}^{0}C$
212^{0} Fahrenheit is equivalent to 100^{0} Celsius
90^{0} Fahrenheit is equivalent to 32.2^{0} Celsius
32^{0} Fahrenheit is equivalent to 0^{0} Celsius
$9/5\,C^{0} + 32 = F^{0}$

APPROXIMATE CONVERSION FACTORS

TO CHANGE	TO	MULTIPLY BY
Inches	Centimeters	2.540
Feet	Meters	0.305
Yards	Meters	0.914
Miles	Kilometers	1.609
Square Inches	Square Centimeters	6.451
Square Feet	Square Meters	0.093
Square Yards	Square Meters	0.836
Square Miles	Square Kilometers	2.590
Acres	Square Hectometers	0.405
Cubic Feet	Cubic Meters	0.028
Cubic Yards	Cubic Meters	0.765
Fluid Ounces	Milliliters	29.573
Pints	Liters	0.473
Quarts	Liters	0.946
Gallons	Liters	3.785
Ounces	Grams	28.349
Pounds	Kilograms	0.454
Short Tons	Metric Tons	0.907
Pound-Feet	Newton-Meters	1.356
Pounds per Square Inch	Kilopascals	6.895
Miles per Gallon	Kilometers per Liter	0.425
Miles per Hour	Kilometers per Hour	1.609

TO CHANGE	TO	MULTIPLY BY
Centimeters	Inches	0.394
Meters	Feet	3.280
Meters	Yards	1.094
Kilometers	Miles	0.621
Square Centimeters	Square Inches	0.155
Square Meters	Square Feet	10.764
Square Meters	Square Yards	1.196
Square Kilometers	Square Miles	0.386
Square Hectometers	Acres	2.471
Cubic Meters	Cubic Feet	35.315
Cubic Meters	Cubic Yards	1.308
Milliliters	Fluid Ounces	0.034
Liters	Pints	2.113
Liters	Quarts	1.057
Liters	Gallons	0.264
Grams	Ounces	0.035
Kilograms	Pounds	2.205
Metric Tons	Short Tons	1.102
Newton-Meters	Pound-Feet	0.738
Kilopascals	Pounds per Square Inch	0.145